EFFECT OF RATE AND SEASON OF APPLICATION OF AMINOCYCLOPYRACHLOR ON THE CONTROL OF *ACACIA FARNESIANA* (L.) WILLD. IN SOUTH TEXAS

A Thesis

by

JOSHUA ALLAN MCGINTY

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2012

Major Subject: Rangeland Ecology and Management

Effect of Rate and Season of Application of Aminocyclopyrachlor on the Control of

Acacia farnesiana (L.) Willd. in South Texas

EFFECT OF RATE AND SEASON OF APPLICATION OF AMINOCYCLOPYRACHLOR ON THE CONTROL OF *ACACIA FARNESIANA* (L.) WILLD. IN SOUTH TEXAS

A Thesis

by

JOSHUA ALLAN MCGINTY

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Co-Chairs of Committee,	Fred E. Smeins
	William E. Rogers
Committee Members,	Scott A. Senseman
	Robert K. Lyons
Head of Department,	Steven G. Whisenant

May 2012

Major Subject: Rangeland Ecology and Management

ABSTRACT

Effect of Rate and Season of Application of Aminocyclopyrachlor on the Control of *Acacia farnesiana* (L.) Willd. in South Texas.

(May 2012)

Joshua Allan McGinty, B.S., Angelo State University

Co-Chairs of Advisory Committee: Dr. Fred E. Smeins
Dr. William E. Rogers

This study was conducted on two rangeland sites in south Texas with large populations of huisache (*Acacia farnesiana* (L.) Willd.); the Bush Ranch in Goliad County, and the Hitchcock Ranch in Bee County. The purpose of the study was to evaluate the effect of three herbicide treatments and three seasons of application on 1) apparent mortality of huisache, 2) huisache canopy cover, 3) huisache stem density, and 4) herbaceous ground cover.

Herbicide treatments included aminocyclopyrachlor alone at a rate of 0.315 kg a.i. ha^{-1}, aminocyclopyrachlor + triclopyr at a rate of 0.210 kg a.i. ha^{-1} + 0.420 kg a.e. ha^{-1}, and triclopyr + picloram at a rate of 0.560 kg a.e. ha^{-1} + 0.560 kg a.e. ha^{-1}. Herbicide treatments were applied over 3 x 30 m plots containing previously mowed huisache in May, July, and October of 2010 with ground-broadcast equipment at a rate of 140 L ha^{-1}. Randomly selected huisache individuals and herbaceous ground cover at randomly selected points were monitored for the duration of the study.

Statistical analyses of huisache mortality, canopy area, and stem densities revealed that at both sites one year after treatment, huisache mortality across the three seasons of application was consistently higher in plots treated with aminocyclopyrachlor + triclopyr (50 to 99%) versus those treated with aminocyclopyrachlor alone (16 to 78%) or triclopyr + picloram (4 to 70%). This mixture also provided the greatest reductions in huisache canopy area (60 to 99% reduction) and stem density (61 to 99% reduction). Also at both sites, spring applications consistently provided the greatest huisache control and canopy and stem reductions. Herbicide treatment and season of application had little effect on post-treatment herbaceous ground cover, likely due to extreme drought conditions in 2011.

Of the possible combinations of seasons of application and herbicide treatments, the application in the spring of aminocyclopyrachlor plus triclopyr provided the most desirable results in terms of huisache mortality, canopy reduction, and stem density reduction. However, for sites invaded by huisache that are located near to potentially susceptible crops, the application of aminocyclopyrachlor plus triclopyr or aminocyclopyrachlor alone in the fall after the harvest of those crops may be more appropriate in order to avoid non-target injury while still providing acceptable huisache control.

ACKNOWLEDGEMENTS

I would like to thank my committee co-chairs, Dr. Smeins and Dr. Rogers for their patience and guidance throughout this study, and my committee members, Dr. Lyons and Dr. Senseman, for their help and support during this research project.

I would like to thank DuPont for providing the funding necessary for this project and DuPont employees Eric Castner, Jay Ellis, and Clifton Brister for their hard work during this study and for providing me with the opportunity and resources to conduct this research. I also would like to thank Stan Reinke for his help locating suitable research sites and for his assistance throughout this study, and to Dr. Wayne Hanselka for his assistance while applying herbicide treatments and for sharing his invaluable knowledge of south Texas rangelands. I also wish to extend special thanks to Chris Bush and Johnny and Sarah Hitchcock for allowing me to conduct this research on their properties.

Finally, I would like to thank my father, Dr. Allan McGinty, for first sparking my interest in this field of study and for his advice throughout this research project.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

TABLE Page

CHAPTER I

INTRODUCTION

Acacia farnesiana (L.) Willd., commonly known as huisache (pronounced WEE-satch), is a thorny shrub or small tree with multiple stems growing to 9 m high (Vines 1960; Hart et al. 2008). It occurs as far north as Texas, east to Florida, west to New Mexico and Arizona, and south to northern South America (Vines 1960). Smith and Rechenthin (1964) estimated that huisache occurred on approximately 1.1 million hectares of rangeland in Texas, however, the density and canopy cover within that range has increased since their surveys (Scifres 1980; Scifres et al. 1982a). Huisache occurs on moist to seasonally dry, disturbed sites below 1500 m, on a variety of soils (Clarke et al. 1989; Ebinger et al. 2002). In south Texas, it is commonly found on disturbed and overgrazed rangeland and pastureland, typically growing in close association with several other woody species (Van Auken et al. 1985). It is an aggressive invader of disturbed sites and can have a significant negative impact on forage production and the vegetation composition of affected sites (Scifres et al. 1982a).

Aminocyclopyrachlor, the active ingredient of a newly developed herbicide from DuPont (Wilmington, DE) currently known as DPX-MAT28, belongs to a new group of herbicides known as pyrimidine carboxylic acids. Aminocyclopyrachlor is thought to act as an auxin mimic after it is absorbed by the plant, causing epinasty of leaves,

---

This thesis follows the style of *Rangeland Ecology and Management*.

inhibition of shoot and root growth, chloroplast damage, chlorosis, vascular system damage, and eventual death (Ashton and Crafts 1981; Devine et al. 1993; Grossman 2000; DuPont 2009). This chemical is currently being developed for rangeland and pasture use for the control of woody plants and broadleaved weeds (DuPont 2009).

The primary purpose of this study is to evaluate the effectiveness of different rates of aminocyclopyrachlor and the season of application of these herbicide treatments on controlling huisache on south Texas rangelands that have been degraded by woody encroachment. This will be addressed by the following hypotheses and objectives:

Hypothesis I

The application rate of aminocyclopyrachlor and mixtures of other herbicides will affect growth and survivorship of *A. farnesiana* and herbaceous composition.

Hypothesis II

Season of application of herbicide treatments will affect growth and survivorship of *A. farnesiana* and herbaceous composition.

Hypothesis III

The application rate and timing of application of aminocyclopyrachlor will exhibit an interactive effect on growth and survivorship of *A. farnesiana* and herbaceous composition.

Objective I. Evaluate changes in canopy, living stems, and mortality of *A. farnesiana* in regards to herbicide mixture and season of application.

Objective II. Evaluate changes in foliar cover of non-target herbaceous plant growth forms in regards to herbicide mixture and season of application.

CHAPTER II

LITERATURE REVIEW

Morphology of *Acacia farnesiana* (L.) Willd.

Acacia farnesiana (L.) Willd. is a native thorny shrub or small tree that grows to 9 m in height and flowers from February to March (Vines 1960; Stubbendieck et al. 2003). It occurs from northern South America to Texas, and from Arizona to Florida on a variety of soils (Vines 1960; Stubbendieck et al. 2003).

The inflorescence is a dense globose head that is found either solitary or in clusters of 2 to 5 heads (Vines 1960; Stubbendieck et al. 2003; Hart et al. 2008). The flower is yellow, fragrant, perfect, with five petals, and numerous stamen (Vines 1960; Stubbendieck et al. 2003). The corolla is tubular, five-lobed, and approximately 2 mm long (Vines 1960). The fruit of *A. farnesiana* is a legume that is woody, straight or curved, 20 mm to 80 mm long, brown to black, flattened on one side, sharp-pointed, with seeds in solitary compartments (Vines 1960; Stubbendieck et al. 2003). Scifres (1974) found that the mean seed dimensions are 3 mm wide by 5 mm long. The seeds are dark brown to black in color with a smooth seed coat (Scifres 1974). The average seed mass is 61 mg (Jurado et al. 2001). Seeds have a hard seed coat that requires scarification for germination (Vora 1989). Germination of huisache seeds in petri dishes at an optimum temperature of 30^{o} C has been observed to range from 55 to 75% (Scifres 1974).

The leaves are bipinnately compound, alternate, 2.5 mm to 10 cm long, gray-green, and glabrous or finely pubescent (Vines 1960; Hart et al. 2008). Leaves from *A. farnesiana* in Texas and northern Mexico are glabrous, while those found on individuals from western Mexico are densely pubescent (Clarke 1989). Mature leaves exhibit a thick waxy cuticle, while younger leaves have a very thin cuticle (Scifres et al. 1982a). Pinnae are found in 2-8 pairs with 10-25 pairs of leaflets that are linear, 2 mm to 6 mm long, 1 mm wide, with an acute apex (Vines 1960). Petioles are pubescent and usually greater than 6 mm long (Ebinger et al. 2002).The stems have paired stipular spines 6 mm to 14 mm long (Scifres et al. 1982a; Stubbendieck et al. 2003; Hart et al. 2008). Stems are reddish in color and close-grained (Vines 1960). Huisache readily sprouts new shoots from buds found on residual stem tissue following disruption of apical dominance (Scifres et al. 1982a).

Confusion with *Acacia smallii.* Isely

Isely (1969) recognized a separate species, *Acacia smallii* Isely, in the southern United States. *A. smallii* was differentiated from *A. farnesiana* by its smaller leaflets and the absence of obvious secondary venation. Ebinger et al. (2002) examined over 600 specimens of A. *farnesiana* collected from several locations across its range, and concluded that *A. smallii* was an example of the variability exhibited by *A. farnesiana* and was not a separate species. Clarke et al. (1989) also concluded that *A. smallii* and *A. farnesiana* were the same species based on their findings that *A. smallii* could not consistently be separated from *A. farnesiana* based on the characteristics defined by Isely (1969); however, the literature refers to huisache by both names.

Establishment

A study by Lohstroh and Van Auken (1987) indicated that huisache thrives in full sunlight while shade greatly inhibits its growth, suggesting that it is likely an early colonizer of overgrazed grasslands and abandoned cultivated fields. The mean percentage of spring germination of huisache seeds in full sun versus shade has been shown to not be significantly different, while the mean percentage of germination in the fall has been shown to decrease from 85% in full sun to 65% in shade (Jurado et al. 2001). Scifres (1974) found that more seeds germinated at 30° C than at 16, 21, or 38° C and that moisture had no apparent influence on germination at optimum temperature.

Huisache is a nitrogen fixing legume (Johnson et al. 1995; Polley et al. 1997) whose growth appears to have a very low soil nitrogen requirement, which further increases its advantage during the initial stages of succession on depleted range sites, but growth may be limited by the availability of other soil nutrients (Van Auken et al. 1985; Van Auken and Bush 1985; Bush and Van Auken 1986, 1987; Bush et al. 2006). Supplementation of nitrogen in native soils has been shown to have no effect on stimulating huisache growth (Van Auken and Bush 1985). Studies conducted by Van Auken and Bush (1985, 1987, 2006) on terraces of the San Antonio River found that huisache dominated abandoned cultivated sites where there was high light and low nitrogen availability until 25 to 30 years after abandonment, when higher levels of nitrogen and low light availability favored other woody species such as sugar hackberry (*Celtis laevigata* Willd. var. *laevigata),* which is more shade tolerant and has the ability to utilize higher levels of nitrogen. Huisache seedlings are extremely competitive and have been shown to out-compete honey mesquite (*Prosopis glandulosa* Torr.) and existing herbaceous vegetation when it establishes on a native range site (Meyer and Bovey 1982).

Effects of Huisache on Rangelands

Huisache has been shown to have a negative effect on warm and cool-season grass production when its canopy cover increases above 30% (Scifres et al. 1982b). Below 30% canopy cover, cool-season grass species such as Texas wintergrass (*Nassella leucotricha* (Trin. & Rupr.) Barkworth) are promoted while warm-season grasses are suppressed (Scifres et al. 1982b). Huisache has high seedling establishment on sites that are frequently mowed, likely due to its rapidly growing and early successional life history characteristics (Meyers and Bovey 1982). Huisache exhibits very rapid initial elongation of sprouts following top removal and is often the dominant woody species found in frequently mowed sites in south Texas (Powell et al. 1972). A study by Powell and Box (1967) indicated that huisache exhibited the most vigorous resprouting and regrowth following mowing on south Texas mixed brush sites in San Patricio County. After mowing is ceased, other brush species become more common (Powell et al. 1972).

Huisache is potentially an important part of wildlife habitat in south Texas when managed properly as it provides cover while also promoting cool-season grasses such as Texas wintergrass, which has been shown to be an important component of white-tail deer (*Odocoileus virginianus*) diets (Scifres et al. 1982b). However, when canopy cover exceeds 30%, huisache begins to suppress all herbaceous plants beneath the canopy (Scifres et al. 1982b). Huisache leaves are poor in forage value for wildlife and livestock, while the legumes are utilized as food by wildlife (Stubbendieck et al. 2003; Hart et al. 2008).

Previous Control Methods

Mechanical. Huisache resprouts rapidly from residual stem tissue below ground following top removal (Scifres et al. 1982a). Simple top removal by the use of mechanical methods such as mowing and roller-chopping can reduce canopy cover temporarily, but are not an effective means of killing mature plants due to the abundance of resprouts (Powell et al. 1972). In order to effectively kill the plant, mechanical control methods must be capable of removing stem tissue at a depth of 5-20 cm below the soil surface, depending on the maturity of the individual plant (Bontrager et al. 1979). This depth corresponds with the depth of the junction of the first lateral root with the stems (Bontrager et al. 1979). This is best achieved by the use of grubbing individual plants or by the use of a root plow across the landscape, both of which greatly disturbs the soil and can potentially encourage the growth of other undesirable understory woody species (Carter 1958).

Prescribed Fire. Huisache has been shown to increase in canopy cover following both fall and winter burning (Box and White 1969). While prescribed fire can temporarily reduce canopy cover by simple top removal, preburn height has been observed to fully recover within two growing seasons (Rasmussen et al. 1983). While not effective for huisache control, winter burning can result in increased palatability of huisache regrowth to livestock and wildlife when compared to unburned huisache (Scifres and Hamilton 1993). Conducting prescribed burning of moderate to dense stands of huisache without first utilizing some other method of reducing huisache canopy cover can be difficult due to the reductions in fine fuel load and continuity that are frequently observed beneath huisache canopies (Scifres and Hamilton 1993; Scifres et al. 1982b).

Chemical. Previous studies show that huisache is resistant to soil or foliage treatments of 2, 4-D and 2, 4, 5-T (removed from market in 1985 by U.S. Environmental Protection Agency), but show that the plant has a susceptibility to picloram applied to the foliage or as a soil spray (Darrow et al. 1953; Bovey et al. 1967; Bovey et al. 1968; Meyer et al. 1976; Scifres 1980). Data from Bovey et al. (1968) shows that applications of picloram at a rate of 2.24 kg ha^{-1} (1 lb ac^{-1}) resulted in defoliations of 85% in May applications and 93% in October applications. Foliar applications of picloram applied aerially at rates of 1.12, 2.24, and 3.36 kg ha^{-1} (1, 2, and 3 lb ac^{-1}) in May, June, July, and October have been shown to temporarily reduce huisache canopy cover (Bovey et al. 1970). Picloram applied in early spring, did not provide significant canopy reduction (Bovey et al. 1968 and 1970), but achieved effective control of honey mesquite (*Prosopis glandulosa* Torr.) (Bovey et al. 1970). Aerial applications of picloram in May effectively reduced canopy cover of both huisache and honey mesquite (Bovey et al. 1970). Foliar treatments of huisache with several rates of picloram combined with 2, 4, 5-T applied in early summer or early fall provided greater canopy reductions than mid- to late-summer applications, likely due to photo-degradation of the herbicide during hotter and drier environmental conditions during late summer (Bovey et al. 1972). Granular formulations of herbicides have been effectively applied to the soil to achieve huisache canopy reductions when unfavorable weather conditions restrict the use of foliar applied herbicides (Bovey et al. 1969). Granular picloram applied to the soil in the spring or fall at rates above 2.24 kg ha^{-1} (2 lb ac^{-1}) can significantly reduce huisache canopy cover except on heavy clay soils (Bovey et al. 1969; Bovey et al. 1972; Meyer et al. 1976). Huisache located on loam and sandy loam soils can be controlled by pelleted applications of tebuthiuron (*N*-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N*,*N*'-dimethylurea) at a rate of 2.24 kg ha^{-1} (2 lb ac^{-1}) while rates of up to 4.48 kg ha^{-1} (4 lb ac^{-1}) are required for huisache control on soils with higher clay content in order to compensate for binding of the herbicide by soil particles (Scifres 1980). Application of tebuthiuron at rates of 2.24 kg ha^{-1} and higher has been shown to cause damage to desirable grasses (Scifres 1980). Additionally, subsurface applications of bromacil at 8.97 kg ha^{-1} (8 lb ac^{-1}) have been shown to cause 100% mortality of huisache (Bovey and Meyer 1978), however bromacil has been shown to severely damage desirable herbaceous species (Bovey et al. 1970). Currently, there are several recommended broadcast foliar chemical treatments for the control of huisache, which are summarized in Table 1 (McGinty et al. 2010; Pestman 2011).

Table 1. Summary of currently recommended broadcast foliar herbicide treatments for the control of huisache (McGinty et al. 2010; Pestman 2011).

Herbicide	Rate	Application	Expected Control	Cost ha^{-1}
Picloram + Triclopyr	0.56 kg ha^{-1} + 0.56 kg ha^{-1}	Spring, with mature	Low-Moderate	$71.04
Picloram + Clopyralid	0.56 kg ha^{-1} + 0.28 - 0.56 kg ha^{-1}	foliage or fall with	Low-Moderate	$119.72
Picloram:Fluroxypyr (1:1)	1.12 kg ha^{-1}	good soil moisture	Low-Moderate	$103.78
Picloram	0.56 kg ha^{-1}	and foliage.	Low-Moderate	$46.33

Biological. Two main native insects have been shown to affect huisache regrowth following mechanical top removal; treehoppers (*Membracidae*) and long-horned wood-boring beetles (*Cerambycidae*) (Powell et al. 1972). Treehoppers damage the new sprout tips, while the wood-boring beetles damage resprouts close to the mechanically cut stump (Powell et al. 1972). These two insects have been shown to have significant negative effects on elongating huisache sprouts (Powell et al. 1972), though there have not been any efforts to date to intentionally utilize them for huisache control purposes.

Aminocyclopyrachlor

Aminocyclopyrachlor, the common name for 6-amino-5-chloro-2-cyclopropyl-4-pyrimidinecarboxylic acid (Figure 1), is the active ingredient of a new herbicide referred to as DPX-MAT28 being developed by DuPont (Wilmington, DE). It belongs to a new class of chemicals known as pyrimidine carboxylic acids. It is currently being evaluated by the U.S. Environmental Protection Agency (EPA) for registration for weed and brush control. DuPont researchers suggest that aminocyclopyrachlor acts as an auxin mimic by interfering with growth hormones within the plant (DuPont 2009). Auxins are plant growth regulators that are produced in active meristematic tissues that are vital for proper division, differentiation, and elongation of plant cells. Plants that are treated with an auxin-like herbicide initially exhibit increased stomatal opening and an increased rate of photosynthesis. Later, the auxin mimic results in epinasty of stem, leaf, and petiole tissues, root growth inhibition, decreased elongation of internodes, reduced stomatal opening, chloroplast damage, chlorosis, and tissue death. (Ashton and Crafts 1981; Cobb 1992; Devine et al. 1993; Grossman 2000). Aminocyclopyrachlor is absorbed by both the roots and leaves of the plant and is thought to build up within meristematic tissues in the plant. In turf studies, aminocyclopyrachlor has been shown to have a half-life of 37 to 103 days and a half-life of 72 to 128 days on bare ground. The compound is degraded by soil microbes and photolyzation (DuPont 2009).

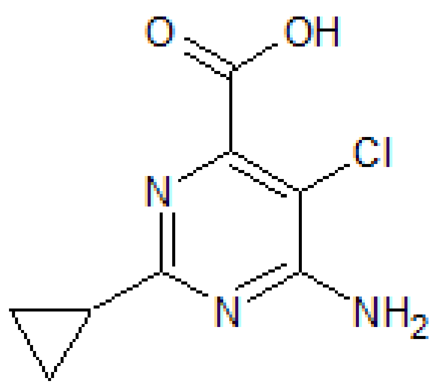

Figure 1. Structure of aminocyclopyrachlor.

In an acute mammalian toxicity study by DuPont, the chemical has an oral LD_{50} of less than 5000 mg kg^{-1}, a dermal LD_{50} of less than 5000 mg kg^{-1}, and an inhalation LD_{50} of less than 5.4 mg L^{-1} (DuPont 2009). It has not been shown to cause skin irritation or sensitization, but is a mild eye irritant (DuPont 2009). Additionally, aminocyclopyrachlor has been shown to have no genetic, subchronic, developmental, reproductive, immunotoxic, or neurotoxic effects (DuPont 2009). Ongoing studies are currently being conducted on chronic toxicity in two-year rat, 18-month mouse, and one-year dog studies (DuPont 2009).

The primary objectives of this study were to evaluate the effectiveness of three different herbicide mixtures and season of treatment on controlling huisache in south Texas. Additionally, this study will evaluate the herbaceous plant response to the different treatments. This study will potentially provide valuable information to south Texas landowners by identifying the most effective herbicide mixture and season of treatment for controlling the encroachment huisache.

CHAPTER III

STUDY SITE DESCRIPTIONS

This study utilized two sites in close proximity to each other in south Texas that are both heavily invaded by huisache. The sites were located on the Bush Ranch in Goliad County, Texas, and the Hitchcock Ranch in Bee County, Texas (Figure 2). The Bush Ranch is located on the west side of SH 183, approximately 18.5 km south of Goliad at lat 28°29’44”N, long 97°20’03”W. The Hitchcock Ranch is located on the north side of SH 202, approximately 2 km east of the intersection of SH 202 and SH 181 on the east side of Beeville at lat 28°22’52”N, long 97°42’10”W. Both sites have been grazed by cattle and have had a varied management history up until the establishment of research plots in March 2010.

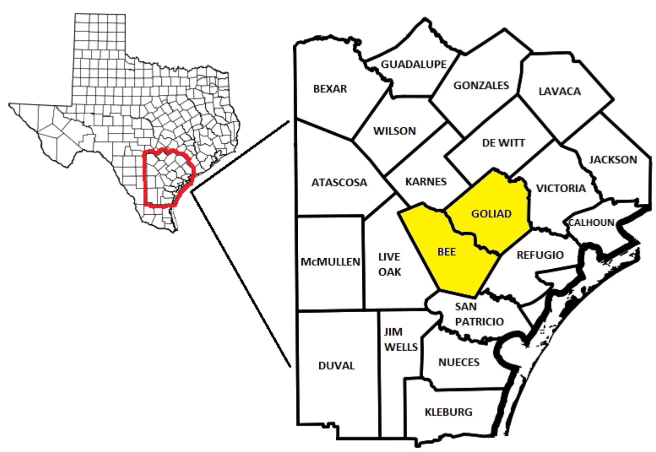

Figure 2. County map of Texas with Goliad and Bee counties highlighted.

The Bush Ranch in Goliad County is located on the Gulf Coastal Prairie Major Land Resource Area (Major Land Resource Area Explorer 2011). This region is typified by level plains that are less than 50 m in elevation and follow the edge of the Gulf of Mexico (Major Land Resource Area Explorer 2011). The elevation at the study site on the Bush Ranch is approximately 35 m as measured with a handheld global positioning system (GPS) unit. Goliad, TX receives 980 mm of mean annual precipitation with the majority of that moisture arriving in May through June and September through October (Figure 3). The mean minimum temperature is 6.3° C in January and the mean maximum temperature is 35.6° C in August (Figure 3). This region has an average frost-free period of 325 days (Major Land Resource Area Explorer 2011). Soil at the Bush Ranch site is a Wyick fine sandy loam at zero to one percent slopes (Web Soil Survey 2011). Wyick fine sandy loams are classified as fine-loamy, hyperthermic Oxyaquic Haplustalfs and are formed from loamy fluviomarine parent material (Web Soil Survey 2011). These are moderately well drained soils with very low water holding capacity that are characterized as a fine sandy loam over a sandy clay loam (Web Soil Survey 2011).

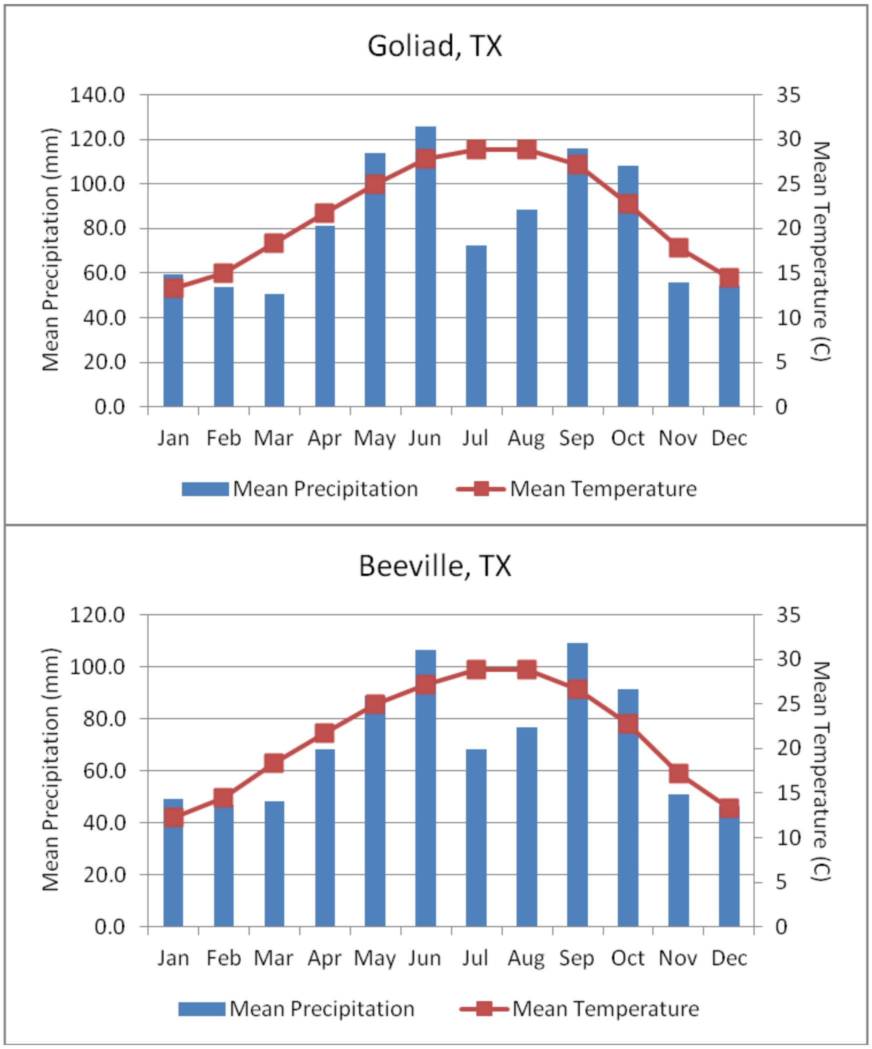

Figure 3. Mean monthly precipitation and temperature for Goliad and Beeville, TX (Southern Regional Climate Center 2011a and 2011b).

The Hitchcock Ranch in Bee County is located within the Northern Rio Grande Plains Major Land Resource Area (Major Land Resource Area Explorer 2011). This area is identified by its gently rolling terrain that is nearly level with elevations ranging from 60 to 305 m (Major Land Resource Area Explorer 2011). The elevation at the study site on the Hitchcock Ranch is approximately 60 m as measured by a Garmin handheld GPS unit. The mean annual precipitation in Beeville, TX is 850 mm with the majority of that precipitation occurring in June and September (Figure 3). The average minimum temperature is 6.2° C in January and the average maximum temperature is 34.8° C in July and August (Figure 3). The mean frost-free period in this region is 315 days (Major Land Resource Area Explorer 2011). Soil at the Hitchcock Ranch site is a Weesatche fine sandy loam at one to three percent slopes (Web Soil Survey 2011). Weesatche fine sandy loams are classified as fine-loamy hyperthermic Typic Argiustolls and are formed from loamy alluvium parent material (Web Soil Survey 2011). These are well drained soils with high water holding capacity that are characterized as a fine sandy loam over sandy clay loams (Web Soil Survey 2011).

Historically, both sites have been mowed annually in the spring or early summer to reduce woody canopy cover and promote herbaceous growth for grazing by cattle. Nevertheless, abundant woody canopy cover persists at both sites. Woody vegetation on the Bush Ranch site is comprised of multi-stemmed huisache and honey mesquite. Grass composition is dominated by King Ranch bluestem (*Bothriochloa ischaemum* (L.) Keng var. *songarica* (Rupr. ex Fisch. & C.A. Mey.), with some brown-seed paspalum (*Paspalum plicatulum* Michx.) and silver bluestem (*Bothriochloa laguroides* (D.C.) Herter.). On the Hitchcock Ranch, woody vegetation is also mostly huisache and honey mesquite, but with scattered brasil (*Condalia hookeri* M.C. Johnst.), hog-plum (*Colubrina texensis* (Torr. & A. Gray) A. Gray), and retama (*Parkinsonia aculeate* L.). Grass composition at the Hitchcock ranch is also dominated by King Ranch bluestem.

CHAPTER IV

METHODS

Experimental Design

In order to assess the efficacy of aminocyclopyrachlor compared to traditional herbicide treatments, as well as the effect of the season of application of herbicide treatment, a randomized study was established at both the Bush Ranch and the Hitchcock Ranch. Three herbicide mixtures were applied during the spring, summer, and fall with four replications of each. Untreated controls were also included for each season of application, which resulted in a total of 48 experimental plots at each site. Plots were placed on relatively level sites with the same soil texture according to the NRCS soil survey (Web Soil Survey 2011). Research plots had been mowed approximately one year prior to the beginning of the study. Individual plots were 3 x 30 m with buffer strips of 4 m between each plot to reduce herbicide drift from adjacent plots. At the Bush Ranch, plots were arranged side-by-side along SH 183 in a strip between a ranch road and the perimeter fence and assigned numbers 1-48, starting at the north end of the plots (Figure 4). At the Hitchcock Ranch, plots were arranged in a grid pattern to fit the shape of the pasture and were also assigned numbers 1-48 as they appeared in the grid (Figure 5). Experimental treatments of herbicide mixture and application time were randomly assigned to each plot. The individual plot assignments of herbicide mixture and application time for each site can be found in Table 2.

Figure 4. Layout of research plots at Bush Ranch

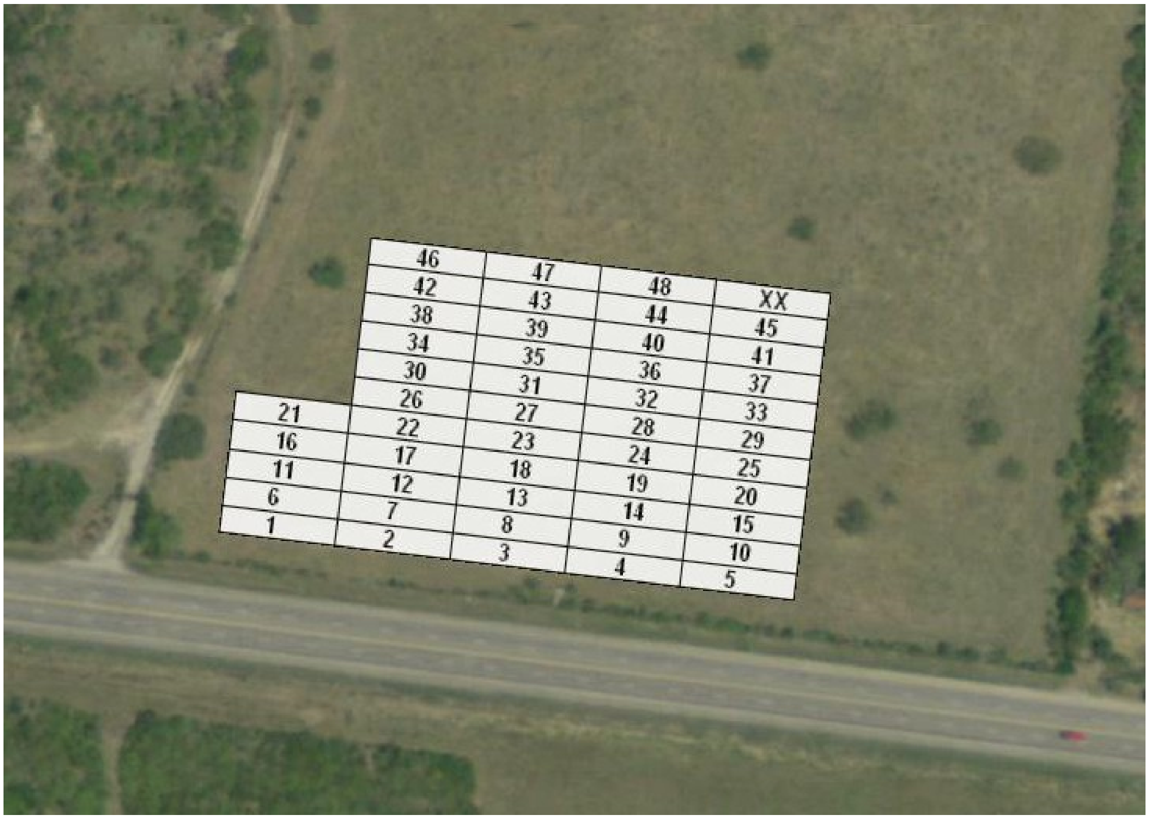

Figure 5. Layout of research plots at Hitchcock Ranch.

Table 2. Random assignment of treatment and season of application to individual plots.

Bush Ranch			Hitchcock Ranch		
Plot #	Treatment	Season	Plot #	Treatment	Season
1	MAT	Summer	1	MAT+REM	Fall
2	REM+TOR	Spring	2	MAT	Summer
3	MAT+REM	Spring	3	MAT	Spring
4	Control	Summer	4	MAT+REM	Spring
5	MAT+REM	Spring	5	REM+TOR	Summer
6	MAT	Spring	6	MAT+REM	Summer
7	MAT	Spring	7	Control	Summer
8	MAT	Spring	8	MAT	Fall
9	Control	Fall	9	MAT	Fall
10	MAT+REM	Summer	10	MAT+REM	Summer
11	REM+TOR	Fall	11	Control	Fall
12	Control	Summer	12	Control	Spring
13	Control	Fall	13	MAT+REM	Fall
14	REM+TOR	Fall	14	Control	Summer
15	Control	Fall	15	MAT+REM	Fall
16	MAT+REM	Summer	16	MAT+REM	Summer
17	REM+TOR	Summer	17	MAT	Spring
18	Control	Spring	18	MAT	Summer
19	Control	Fall	19	REM+TOR	Fall
20	MAT	Fall	20	Control	Summer
21	Control	Spring	21	MAT	Summer
22	Control	Spring	22	Control	Spring
23	REM+TOR	Summer	23	REM+TOR	Summer
24	MAT	Summer	24	MAT+REM	Summer
25	MAT	Summer	25	MAT+REM	Fall
26	REM+TOR	Spring	26	REM+TOR	Fall
27	MAT+REM	Fall	27	REM+TOR	Spring
28	MAT+REM	Fall	28	MAT+REM	Spring
29	MAT+REM	Spring	29	Control	Summer
30	REM+TOR	Spring	30	REM+TOR	Summer
31	MAT	Fall	31	MAT	Spring
32	MAT	Summer	32	REM+TOR	Spring
33	REM+TOR	Summer	33	MAT	Summer
34	MAT+REM	Summer	34	REM+TOR	Summer
35	MAT+REM	Summer	35	Control	Fall
36	MAT+REM	Spring	36	Control	Fall
37	Control	Summer	37	Control	Fall
38	Control	Spring	38	MAT+REM	Spring

Table 2. Continued

Bush Ranch			Hitchcock Ranch		
Plot #	Treatment	Season	Plot #	Treatment	Season
39	Control	Summer	39	Control	Spring
40	REM+TOR	Spring	40	MAT	Fall
41	REM+TOR	Fall	41	REM+TOR	Spring
42	MAT	Fall	42	REM+TOR	Spring
43	MAT	Fall	43	REM+TOR	Fall
44	MAT	Spring	44	MAT+REM	Spring
45	REM+TOR	Fall	45	Control	Spring
46	MAT+REM	Fall	46	MAT	Fall
47	MAT+REM	Fall	47	MAT	Spring
48	REM+TOR	Summer	48	REM+TOR	Fall

Herbicide Treatments and Application

Three different herbicide mixtures were tested. All three herbicide treatments included a modified vegetable oil and organosilicone surfactant blend known by the trade name Dyne-Amic (Helena Chemical Company, Collierville, TN) at 0.50% (v/v) to increase absorption into the plant. The first treatment contains 0.210 kg active ingredient (a.i.) ha^{-1} of MAT28 and 0.420 kg acid equivalent (a.e.) ha^{-1} of a butoxyethyl ester of triclopyr (0.24 kg a.e. L^{-1}), sold under the trade name Remedy® Ultra (Dow Agrosciences, Indianapolis, IN). The second treatment contains MAT28 alone at a rate of 0.315 kg a.i. ha^{-1}. The third treatment is a currently recommended broadcast treatment for huisache control (McGinty et al. 2010, Pestman 2011) and contains 0.560 kg a.e. ha^{-1} of Remedy® Ultra and 0.560 kg a.e. ha^{-1} of a potassium salt of picloram (0.48 kg a.e. L^{-1}) sold under the trade name Tordon® 22K (Dow Agrosciences, Indianapolis, IN). Abbreviations for these herbicide treatments can be found in Table 3 and will be used throughout the remainder of this thesis. Untreated controls were included for each season of application.

Herbicide applications were broadcast using Turbo TeeJet 11002 nozzles (Spraying Systems Co., Wheaton, IL) on a tractor-mounted spray boom at a rate of 140 L ha^{-1} (Figure 6). The tractor-mounted spray boom was used for the spring and fall applications. For the summer application, excessive rainfall prior to the application prevented the use of the tractor. In place of the tractor-mounted boom, a handheld boom was used during the summer application (Figure 7). A metronome was used while spraying with this boom to keep walking speeds consistent. During each treatment the air temperature, relative humidity, wind speed, and soil temperature at 30 cm measured with a Reotemp soil thermometer were recorded.

Table 3. Abbreviations to be used for herbicide treatments

Herbicide	Rate kg a.e./ha	Abbreviation
Aminocyclopyrachlor + Remedy® Ultra	0.210 + 0.420	MAT+REM
Aminocyclopyrachlor	0.315	MAT
Remedy® Ultra + Tordon® 22K	0.560 + 0.560	REM+TOR
Control	N/A	CONT

Figure 6. Tractor-mounted spray boom.

Figure 7. Hand-held spray boom used to spray summer plots on July 16, 2010.

Vegetation Sampling

A 30-m line transect was established at the center of the long axis of each plot. Twenty random points were selected along each transect and the nearest individual huisache was sampled and tagged with an identification number for future sampling. The direction and distance to each tagged plant was recorded. Individual plant sampling consists of measurements of the number of living stems per plant, canopy height, and canopy width along a north-south line and an east-west line in order to calculate a mean horizontal canopy area with the equation:

$$horizontal\ canopy\ area = \left(\left(\frac{north \leftrightarrow south\ width}{2} \right) * \left(\frac{east \leftrightarrow west\ width}{2} \right) * \pi \right).$$

At five randomly selected points along each transect, the percent cover of woody plant, grass, forb, litter, and bare ground was visually estimated to within five percent within a 1-m^2 quadrat. Sampling during 2010 was conducted for all plots at the beginning and end of the growing season, as well as prior to each application for the plots being treated (eg., sampling summer plots prior to summer applications). For 2011, sampling was conducted for all plots at the same time that each treatment had been applied the previous year. For the fall sampling of 2011, the first and last 2-m portion of all plots were excluded from sampling after it was determined that this portion of treated plots was frequently significantly different from the remaining portion of the plots, possibly due to variability when applying the herbicide treatments. Apparent huisache mortality was calculated based on the percentage of individual huisache plants with no living foliage on any stem of that plant. This was performed with two different methods. The first method is based only on the tagged huisache individuals that were previously randomly selected to be monitored for canopy dimensions and stem numbers, while the second method is calculated based on all huisache individuals contained within each plot.

Statistical Analysis

This experiment was set up as a 2-factor, completely randomized design. Data were analyzed using two-way analysis of variance (ANOVA) in JMP 9. Data were then analyzed separately for treatment and season of application using one-way ANOVA in order to isolate effects. Means were then separated using Tukey's honestly significant difference (HSD).

CHAPTER V

RESULTS

Precipitation

Four significant rainfall events occurred at both sites in 2010. In July, Hurricane Alex and Tropical Depression Two produced above average rainfall. Precipitation totals were 200% greater than the July mean at the Bush Ranch and 215% greater than the monthly mean at the Hitchcock Ranch. Tropical Storm Hermine and Hurricane Karl also brought above average rainfall to the area in September with precipitation totals 146% greater than the September mean at the Bush Ranch and 147% greater at the Hitchcock Ranch. Total annual precipitation in 2010 was 7% above the annual mean at the Bush Ranch and 27% above the annual mean at the Hitchcock Ranch.

A severe drought began in 2011. At the time of the first vegetation sampling in May 2011, the Bush Ranch had received approximately 49% of the mean precipitation for the period of January through May 2011, and the Hitchcock Ranch had received approximately 33%. At the sampling in July 2011, the Bush Ranch had received approximately 39% of the mean precipitation since January, and the Hitchcock Ranch had received 26%. At the third vegetation sampling in the beginning of November 2011, the Bush Ranch had received approximately 40% of the mean precipitation since January, and the Hitchcock Ranch had received approximately 21%. Cumulative precipitation for both sites during 2011 was substantially below the long-term mean when compared to 2009 and 2010 (Figure 8).

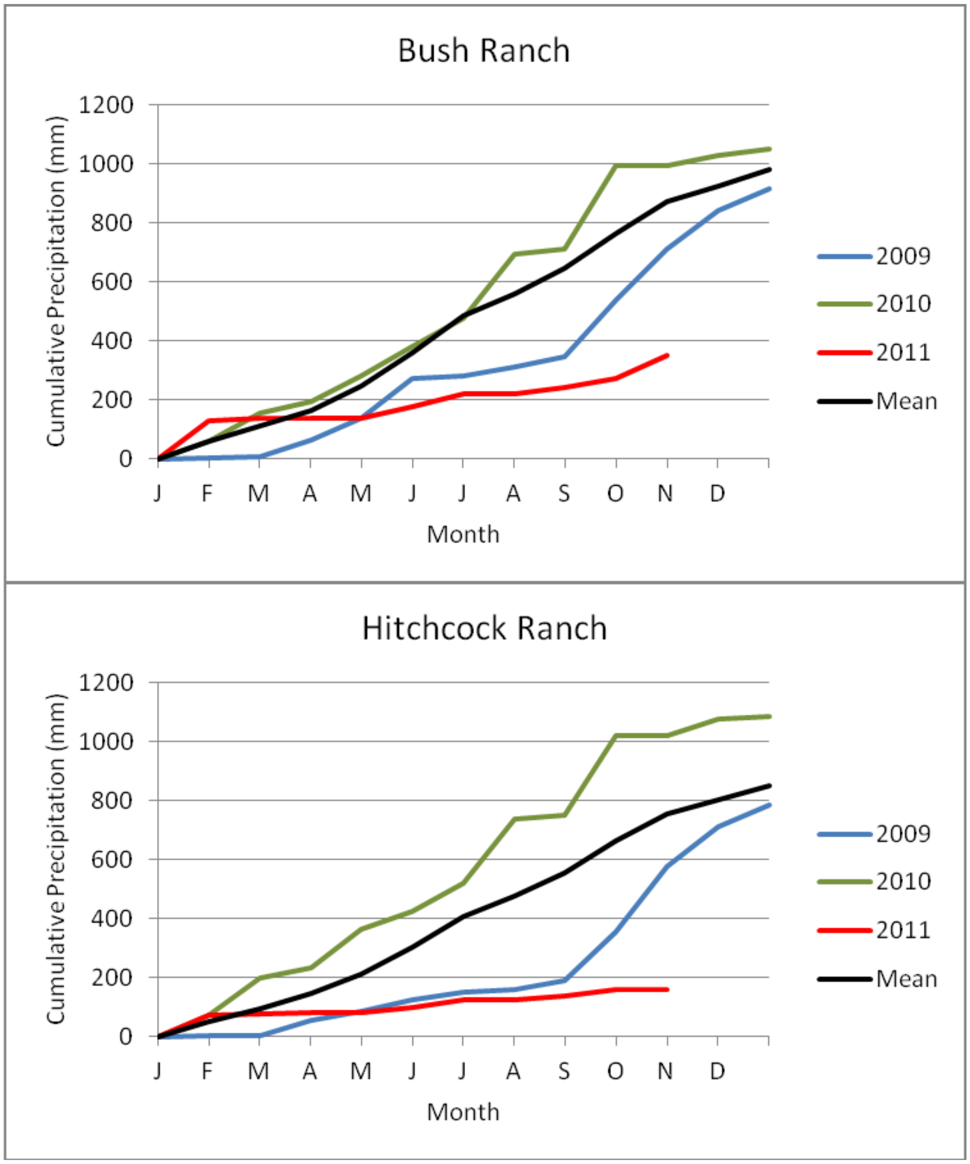

Figure 8. Cumulative annual precipitation for the period of 2009 through November 2011 at research sites.

Pre-Treatment Data

Pre-treatment data for canopy dimensions and number of stems of individual tagged huisache plants and for percent ground cover for all plots was collected during the spring of 2010. The means for individual huisache plant traits were obtained from the randomly selected individuals in each plot that were tagged at the beginning of this study. Pre-treatment data for plots assigned summer or fall herbicide applications was collected prior to each respective herbicide application (Tables 4, 5, and 6).

Table 4. Pre-treatment huisache plant densities across all plots at the Bush and Hitchcock Ranches.

Site	Date Sampled	Mean Huisache Density
		Plants ha^{-1}
Bush Ranch	April 2, 2010	2722
Hitchcock Ranch	April 4, 2010	2562

Table 5. Pre-treatment traits of huisache plants at the Bush and Hitchcock Ranches.

Site	Plots	Date Sampled	Mean Canopy Height	Mean Canopy Area[1]	Mean Stems	Mean Stems
			m	m^2	$plant^{-1}$	ha^{-1}
Bush Ranch	Spring	April 1-2, 2010	0.89	1.30	5.45	13911
	Summer	May 19, 2010	1.08	1.75	4.97	12687
	Fall	May 20, 2010	1.04	1.73	5.05	14202
	Summer	July 14, 2010	1.15	1.86	5.10	12768
	Fall	Oct 2, 2010	1.25	1.64	5.35	14500
Hitchcock Ranch	Spring	April 3-4, 2010	0.94	1.33	6.10	15045
	Summer	May 22, 2010	1.17	1.44	5.74	13605
	Fall	May 23, 2010	1.20	1.45	5.64	16882
	Summer	July 13, 2010	1.38	1.61	5.93	13857
	Fall	Oct 1, 2010	1.52	1.55	6.08	17088

[1] Horizontal canopy area based on outside dimensions of canopy, including open spaces contained within.

Table 6. Pre-treatment means of percent cover within 1-m^2 quadrats at the Bush and Hitchcock Ranches.

Site	Plots	Date Sampled	Forb	Grass	Woody Plant	Litter	Bare Ground
			-------------------------% ground cover-----------------------------				
Bush Ranch	Spring	April 1-2, 2010	27.6	27.8	2.0	31.8	10.8
	Summer	May 19, 2010	25.4	32.6	1.5	25.6	14.9
	Fall	May 20, 2010	19.1	34.6	1.6	32.6	12.1
	Summer	July 14, 2010	28.3	32.5	0.3	17.8	21.2
	Fall	Oct 2, 2010	17.0	66.9	0.4	6.1	9.5
Hitchcock Ranch	Spring	April 3-4, 2010	50.4	22.3	1.9	13.3	12.0
	Summer	May 22, 2010	31.8	31.3	0.4	16.5	20.2
	Fall	May 23, 2010	35.5	32.1	1.3	16.4	14.8
	Summer	July 13, 2010	27.7	43.3	0.5	4.7	23.7
	Fall	Oct 1, 2010	33.3	60.5	0.9	0.9	4.4

Herbicide Applications

At each site prior to treatment, the starting and ending time, air temperature, relative humidity, wind speed, and soil temperature at 30 cm were recorded (Table 7).

Spring Application. Spring plots at both sites were sprayed on May 4, 2010 under clear skies. Plots at the Bush ranch were sprayed between 2:00 and 3:15 PM. Air temperature was 31.1° C, relative humidity 26%, winds 0 to 3 km/h. Soil temperature at 30-cm depth was 25.5° C. Plots at the Hitchcock Ranch were sprayed between 4:30 and 6:00 PM. Air temperature was 32.8° C, relative humidity 22%, winds 0 to 3 km/h. Soil temperature at 30 cm was 26.1° C (Table 7).

Summer Application. Summer plots at both sites were sprayed on July 16, 2010 under mostly clear skies. Due to excessive rainfall in the weeks prior to spraying, muddy conditions prevented the use of the tractor-mounted spray boom. A hand-held spray boom carried by two people was walked across the plots at the same speed as the tractor-mounted spray boom (Figure 6). A metronome was used to keep walking speeds consistent. Spraying at the Hitchcock Ranch was conducted between 7:15 and 9:00 AM. There was a heavy dew, air temperature was 23.6° C, relative humidity 91%, winds were calm, and the soil temperature at 30 cm was 28.8° C. At the Bush Ranch, spraying was conducted between 10:00 AM and 12:00 PM. The research plots had been in standing water for several days prior to spraying and the majority of honey mesquite plants had defoliated due to flooded conditions. There was a moderate dew, air temperature was 32.2° C, relative humidity 63%, winds 5 to 6 km/h, and the soil temperature was 28.3° C (Table 7).

Fall Application. The fall plots at both sites were sprayed on October 12, 2010 under mostly clear skies. Spraying at the Hitchcock Ranch was conducted from 7:30 to 8:15 AM. There was a heavy dew, air temperature was 19.4° C, relative humidity 80%, winds were calm, and soil temperature at 30 cm was 23.3° C. At the Bush Ranch, spraying was conducted from 9:30 to 10:30 AM. There was a moderate dew, air temperature was 25.5° C, relative humidity 80%, winds were 0 to 1 km/h, and soil temperature was 23.3° C (Table 7).

Table 7. Environmental conditions at herbicide applications

Site	Date	Start	End	Temp. °C	R.H. %	Wind km/h	Soil Temp. °C
Bush	5/4/2010	2:00 PM	3:15 PM	31.1	26	0-3	25.5
Hitchcock	5/4/2010	4:30 PM	6:00 PM	32.8	22	0-3	26.1
Bush	7/16/2010	10:00 AM	12:00 PM	32.2	63	5-6	28.3
Hitchcock	7/16/2010	7:15 AM	9:00 AM	23.6	91	Calm	28.8
Bush	10/12/2010	9:30 AM	10:30 AM	25.5	80	0-1	23.3
Hitchcock	10/12/2010	7:30 AM	8:15 AM	19.4	80	Calm	23.3

Huisache Response

Apparent Mortality. Apparent mortality of huisache was calculated using two separate methods. The first method was based only on the tagged individuals within each plot, while the second method was based on all individual huisache plants located within each plot. It was determined that the results from these two methods were not significantly different from each other. Thus, only results obtained from tagged huisache individuals will be presented for detailed analysis in this chapter. Results from the second method can be found in Appendix C.

Mean huisache apparent mortality values obtained at the end of the growing season in 2011 ranged from 0.0 to 78.2% at the Bush Ranch and from 0.0 to 98.7% at the Hitchcock Ranch (Table 8). A two-way ANOVA of huisache apparent mortality at the Bush Ranch showed there was not a significant main effect of season of application, ($F(2,36) =0 .12$, $p = .8883$), but there was a significant main effect of treatment, ($F(3,36) = 30.56$, $p < .0001$), and a significant interaction between season of application and treatment, ($F(6,36) = 4.47$, $p = .0018$). Huisache mortality remained fairly consistent across the three seasons of application for MAT+REM, MAT, and CONT treatments, whereas mortality decreased dramatically for the REM+TOR treatments applied in the fall (Table 8) (Figure 9).

At the Hitchcock Ranch, the two-way ANOVA showed there were significant main effects of season of application, ($F(2,36) = 38.59$, $p < .0001$), and treatment type, ($F(3,36) = 71.11$, $p < .0001$), as well as a significant interaction between the two, ($F(6,36) = 7.14$, $p < .0001$). All three herbicide treatments applied during the summer at the Hitchcock Ranch exhibited a significant decrease in huisache control that was not observed at the Bush Ranch (Table 8). The MAT+REM, MAT, and CONT treatments did not experience a significant change in huisache control between the spring and fall applications, whereas the REM+TOR treatment applied in the fall again exhibited a significant decrease in huisache control when compared to the spring application (Figure 9).

Table 8. Effect of season of application and treatment on mean apparent mortality of huisache.

Season of Application	Treatment	Site: Bush Ranch	Site: Hitchcock Ranch
		----------------------% mortality	---------------------
Spring	MAT+REM	57.6 a[1]	98.7 a
Spring	MAT	51.9 a	72.7 ab
Spring	REM+TOR	55.6 a	70.2 ab
Spring	CONT	0.0 b	0.1 d
Summer	MAT+REM	61.6 a	49.8 bc
Summer	MAT	57.5 a	16.1 d
Summer	REM+TOR	55.2 a	14.4 d
Summer	CONT	0.0 b	0.0 d
Fall	MAT+REM	77.3 a	77.9 ab
Fall	MAT	78.2 a	77.2 ab
Fall	REM+TOR	3.8 b	29.2 cd
Fall	CONT	2.5 b	0.0 d

[1] Within a column, means followed by different letters are significantly different at $P<0.05$.

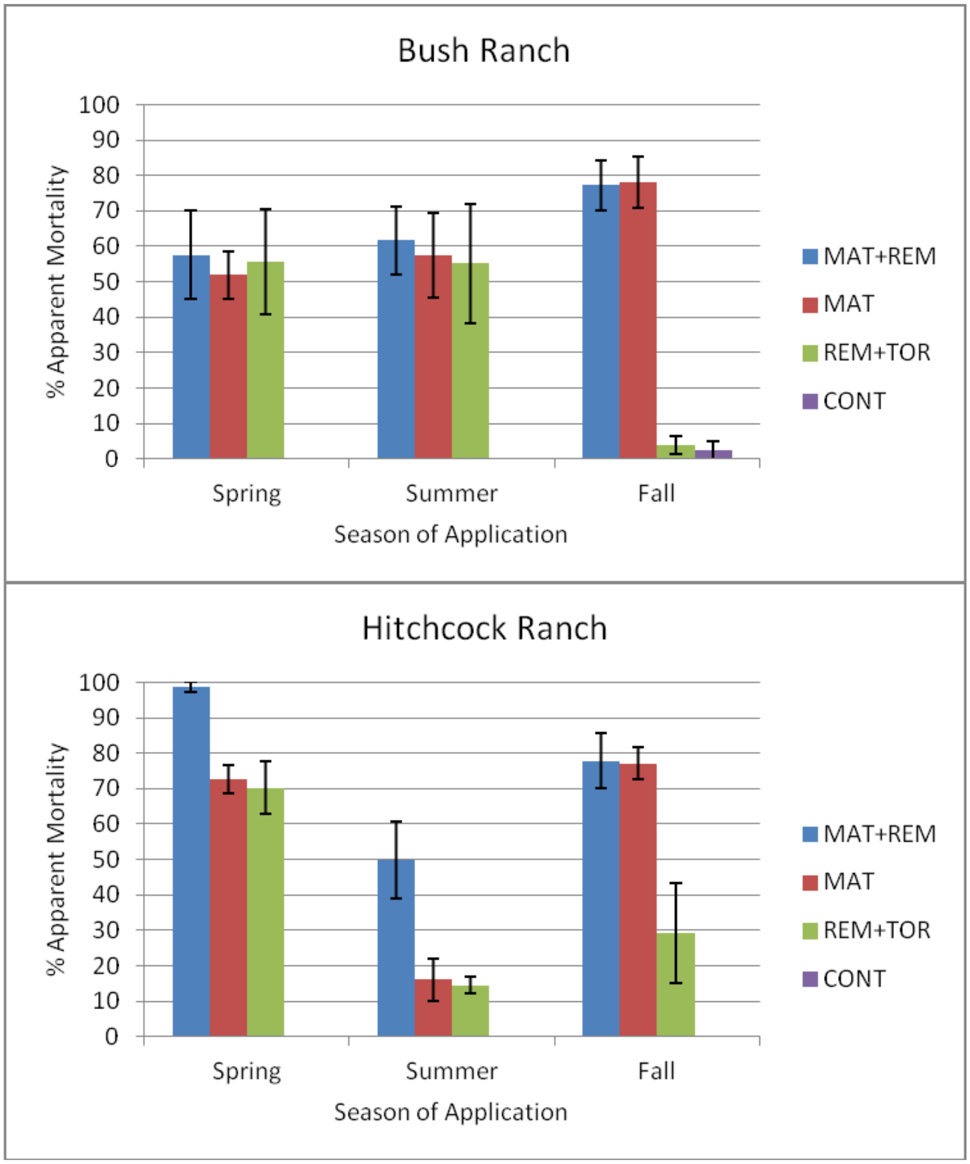

Figure 9. Huisache mortality at both sites.

A one-way ANOVA was conducted to determine the effect of herbicide treatment within each season of application on mean apparent huisache mortality (Table 9). For huisache at the Bush Ranch, treatment had a significant effect on apparent mortality for the spring ($F(3,12) = 7.29$, $p = .0048$), summer ($F(3,12) = 6.52$, $p = .0073$), and fall ($F(3,12) = 65.18$, $p < .0001$), applications. Treatment also had a significant effect on apparent huisache mortality at the Hitchcock Ranch for the spring ($F(3,12) = 97.82$, $p < .0001$), summer ($F(3,12) = 11.19$, $p = .0009$), and fall ($F(3,12) = 20.38$, $p < .0001$) applications.

Table 9. Effect of treatment on mean apparent mortality of huisache within each season of application.

Season of Application	Treatment	Site	
		Bush Ranch	Hitchcock Ranch
		-------------------% mortality------------------	
Spring	MAT+REM	57.6 a[1]	98.7 a
	MAT	55.6 a	72.7 b
	REM+TOR	51.8 a	70.2 b
	CONT	0.0 b	0.1 c
Summer	MAT+REM	61.6 a	49.8 a
	MAT	57.5 a	16.1 b
	REM+TOR	55.2 a	14.4 b
	CONT	0.0 b	0.0 b
Fall	MAT+REM	78.2 a	77.9 a
	MAT	77.3 a	77.2 a
	REM+TOR	3.8 b	29.2 b
	CONT	2.5 b	0.0 b

[1] Within a season of application, means followed by different letters are significantly different at $P<0.05$.

A one-way ANOVA was conducted to determine the effect of season of application within each treatment on mean apparent huisache mortality (Table 10). For huisache at the Bush Ranch, season of application had no significant effect on apparent mortality for MAT+REM ($F(2,9) = 1.10$, $p = .3730$), MAT ($F(2,9) = 2.38$, $p = .1477$), or CONT ($F(2,9) = 1.00$, $p = .4053$), but did have a significant effect for REM+TOR ($F(2,9) = 5.21$, $p = .0314$). Season of application had a significant effect on apparent huisache mortality at the Hitchcock Ranch for MAT+REM ($F(2,9) = 9.87$, $p = .0054$), MAT ($F(2,9) = 47.11$, $p < .0001$), and REM+TOR ($F(2,9) = 9.54$, $p = .0060$), but did not have a significant effect for CONT ($F(2,9) = 1.00$, $p = .4053$).

Table 10. Effect of season of application on mean apparent mortality of huisache within each treatment.

Treatment	Season of Application	Site	
		Bush Ranch	Hitchcock Ranch
		----------------------% mortality---------------------	
MAT+REM	Spring	57.6 a[1]	98.7 a
	Summer	61.6 a	49.8 b
	Fall	77.3 a	77.9 ab
MAT	Spring	51.9 a	72.7 a
	Summer	57.5 a	16.1 b
	Fall	78.2 a	77.2 a
REM+TOR	Spring	55.6 a	70.2 a
	Summer	55.2 ab	14.4 b
	Fall	3.8 b	29.2 b
CONT	Spring	0.0 a	0.1 a
	Summer	0.0 a	0.0 a
	Fall	2.5 a	0.0 a

[1] Within a treatment, means followed by different letters are significantly different at $P<0.05$.

A one-way ANOVA was conducted to determine if the soil temperature at 30 cm depth had a significant effect on apparent huisache mortality. For huisache at the Bush Ranch, soil temperature did not have a significant effect ($F(1,46) = .07$, $p = .7955$), however it did appear to have a significant effect on huisache mortality at the Hitchcock Ranch ($F(1,46) = 4.12$, $p = .0481$), however, this significance is likely due to the decreased level of huisache control observed in summer-applied plots at this site only where soil temperatures were at their highest.

Canopy. Post-treatment mean huisache canopy area values obtained at the end of the growing season in 2011 ranged from 0.06 to 3.22 m^2 at the Bush Ranch and from 0.00 to 2.86 m^2 at the Hitchcock Ranch (Table 11). A two-way ANOVA of huisache at the Bush Ranch showed there was not a significant main effect of season of application, ($F(2,36) = .50$, $p = .6079$), but there was a significant main effect of treatment, ($F(3,36) = 76.42$, $p < .0001$), and a significant interaction between season of application and treatment, ($F(6,36) = 5.40$, $p < .0001$). The two-way ANOVA of huisache canopies at the Hitchcock Ranch showed there were significant main effects of season of application, ($F(2,36) = 6.99$, $p = .0027$) (Table 12), and treatment type, ($F(3,36) = 99.54$, $p < .0001$) (Table 13), with no significant interaction between the two, ($F(6,36) = 1.78$, $p > .1302$).

Table 11. Effect of season of application and treatment on mean huisache canopy area of individual plants.

Season of Application	Treatment	Site: Bush Ranch	Site: Hitchcock Ranch
		------------canopy area (m^2)-----------	
Spring	MAT+REM	0.54 a[1]	0.01 a
Spring	MAT	0.45 a	0.13 a
Spring	REM+TOR	0.54 a	0.39 ab
Spring	CONT	3.22 c	2.30 c
Summer	MAT+REM	0.16 a	0.60 ab
Summer	MAT	0.42 a	0.60 ab
Summer	REM+TOR	0.43 a	1.11 b
Summer	CONT	3.16 c	2.42 c
Fall	MAT+REM	0.18 a	0.09 a
Fall	MAT	0.06 a	0.15 a
Fall	REM+TOR	1.73 b	1.09 b
Fall	CONT	2.17 bc	2.86 c

[1] Within a column, means followed by different letters are significantly different at P<0.05.

Table 12. Effect of season of application on mean huisache canopy area of individual plants at Hitchcock Ranch.

Season of Application	Mean Canopy Area
	-----m^2-----
Spring	0.71 a[1]
Summer	1.18 b
Fall	1.05 b

[1] Means followed by different letters are significantly different at P<0.05.

Table 13. Effect of treatment on mean huisache canopy area of individual plants at Hitchcock Ranch.

Treatment	Mean Canopy Area
	-----m^2-----
MAT+REM	0.23 a[1]
MAT	0.29 a
REM+TOR	0.87 b
CONT	2.53 c

[1] Means followed by different letters are significantly different at P<0.05.

A one-way ANOVA was conducted to determine the effect of herbicide treatment within each season of application on mean huisache canopy area (Table 14). For huisache at the Bush Ranch, treatment had a significant effect on canopy area for the spring ($F(3,12) = 22.91$, $p < .0001$), summer ($F(3,12) = 34.18$, $p < .0001$), and fall ($F(3,12) = 37.98$, $p < .0001$), applications. Treatment also had a significant effect on canopy area at the Hitchcock Ranch for the spring ($F(3,12) = 79.69$, $p < .0001$), summer ($F(3,12) = 16.65$, $p < .0001$), and fall ($F(3,12) = 37.25$, $p < .0001$) applications.

Table 14. Effect of treatment on huisache canopy area of individual plants within each season of application.

Season of Application	Treatment	Site	
		Bush Ranch	Hitchcock Ranch
		------------ canopy area (m^2) -----------	
Spring	MAT+REM	0.54 a[1]	0.01 a
	MAT	0.45 a	0.13 a
	REM+TOR	0.54 a	0.39 a
	CONT	3.22 b	2.30 b
Summer	MAT+REM	0.16 a	0.60 a
	MAT	0.42 a	0.60 a
	REM+TOR	0.43 a	1.11 a
	CONT	3.16 b	2.42 b
Fall	MAT+REM	0.18 a	0.09 a
	MAT	0.06 a	0.15 a
	REM+TOR	1.73 b	1.09 b
	CONT	2.17 b	2.86 c

[1] Within a season of application, means followed by different letters are significantly different at $P<0.05$.

A one-way ANOVA was conducted to determine the effect of season of application within each treatment on mean huisache canopy area (Table 15). For huisache at the Bush Ranch, season of application had no significant effect on canopy area for MAT+REM ($F(2,9) = 3.48$, $p = .0760$), MAT ($F(2,9) = 3.27$, $p = .0857$), or CONT ($F(2,9) = 2.17$, $p = .1705$), but did have a significant effect for REM+TOR ($F(2,9) = 12.12$, $p = .0028$). Season of application had a significant effect on canopy area at the Hitchcock Ranch for MAT+REM ($F(2,9) = 8.32$, $p = .0090$) and MAT ($F(2,9) = 15.55$, $p = .0012$), but did not have a significant effect for REM+TOR ($F(2,9) = 2.12$, $p = .1760$) or CONT ($F(2,9) = 1.99$, $p = .1927$).

Table 15. Effect of season of application on mean huisache canopy area of individual plants within each treatment.

Treatment	Season of Application	Site	
		Bush Ranch	Hitchcock Ranch
		------------ canopy area (m^2) -----------	
MAT+REM	Spring	0.54 a[1]	0.01 a
	Summer	0.16 a	0.60 b
	Fall	0.18 a	0.09 a
MAT	Spring	0.45 a	0.13 a
	Summer	0.42 a	0.60 b
	Fall	0.06 a	0.15 a
REM+TOR	Spring	0.54 a	0.39 a
	Summer	0.43 a	1.11 a
	Fall	1.73 b	1.09 a
CONT	Spring	3.22 a	2.30 a
	Summer	3.16 a	2.42 a
	Fall	2.17 a	2.86 a

[1] Within a treatment, means followed by different letters are significantly different at $P<0.05$.

Time-series graphs were created for percent change in mean huisache canopy area per living plant by treatment for each season of application for both sites (Figures 10 and 11). The data to create these graphs are included in Appendix D. Points in time are expressed as days after treatment (DAT). In these graphs, the increased rate of huisache canopy recovery of plants treated in the fall with REM+TOR compared to those treated with fall-applied MAT+REM and MAT is apparent.

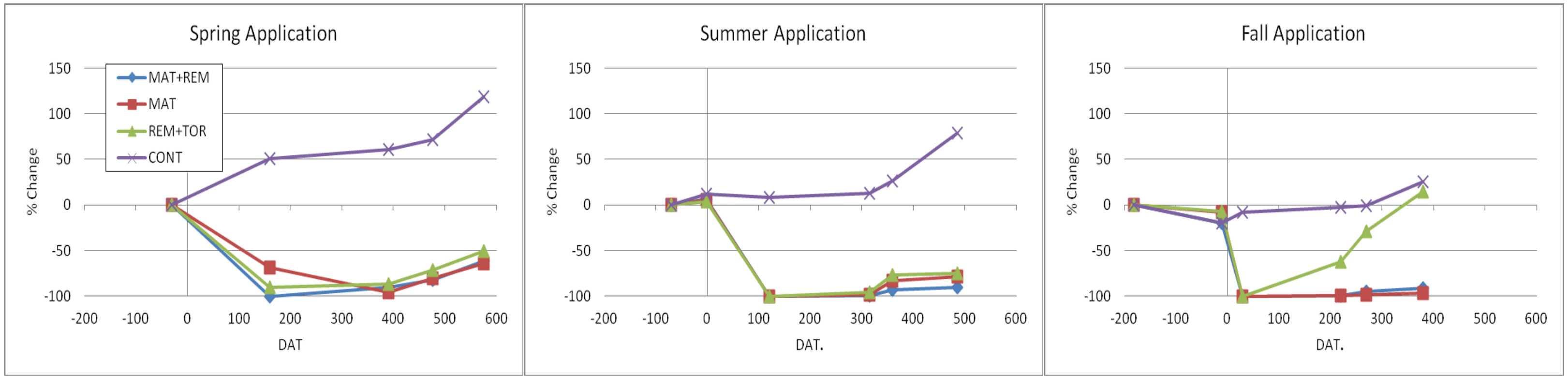

Figure 10. Time-series plots of percent change in mean huisache canopy area per living plant at Bush Ranch.

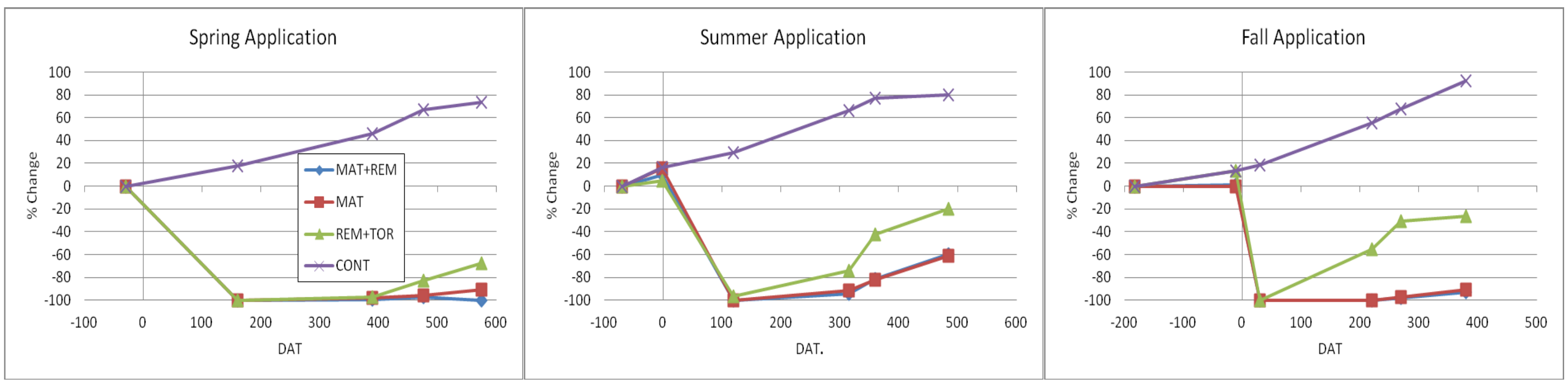

Figure 11. Time-series plots of percent change in mean huisache canopy area per living plant at Hitchcock Ranch.

Stem Density. Post-treatment mean huisache living stem density values obtained at the end of the growing season in 2011 ranged from 790 to 21653 stems ha^{-1} at the Bush Ranch and from 35 to 17370 stems ha^{-1} at the Hitchcock Ranch. A two-way ANOVA of stem densities at the Bush Ranch showed there was a significant main effect of treatment, ($F(3,36) = 22.73$, $p < .0001$) (Table 16), but not of season of application, ($F(2,36) = .88$, $p = .4234$), or the interaction between season of application and treatment, ($F(6,36) = 2.09$, $p = .0791$). The two-way ANOVA of huisache stems at the Hitchcock Ranch also showed there was a significant main effect of treatment, ($F(3,36) = 34.01$, $p < .0001$), but not of season of application, ($F(2,36) = 2.05$, $p = .1435$), or between season of application and treatment, ($F(6,36) = 1.78$, $p = .1315$).

Table 16. Effect of treatment on mean huisache stem density at both sites.

Treatment	Bush Ranch	Hitchcock Ranch
	-------------------- stems ha^{-1}	--------------------
MAT+REM	2170 a[1]	1527 a
MAT	2346 a	2895 ab
REM+TOR	4936 a	6586 b
CONT	18097 b	16678 c

[1] Means followed by different letters are significantly different at P<0.05.

A one-way ANOVA was conducted to determine the effect of herbicide treatment within each season of application on mean huisache stem density (Table 17). For the Bush Ranch, treatment had a significant effect on stem density for the spring ($F(3,12) = 11.01$, $p = .0009$), summer ($F(3,12) = 6.55$, $p = .0072$), and fall ($F(3,12) = 17.84$, $p = .0002$), applications. Treatment also had a significant effect on stem density at the Hitchcock Ranch for the spring ($F(3,12) = 43.04$, $p < .0001$), summer ($F(3,12) = 6.73$, $p = .0065$), and fall ($F(3,12) = 8.01$, $p < .0034$) applications.

Table 17. Effect of treatment on mean huisache stem density within each season of application.

Season of Application	Treatment	Site	
		Bush Ranch	Hitchcock Ranch
		------------ stems ha^{-1} -----------	
Spring	MAT+REM	3231 a[1]	35 a
	MAT	4193 a	1076 a
	REM+TOR	2315 a	1775 a
	CONT	12950 b	17147 b
Summer	MAT+REM	1953 a	3498 a
	MAT	2056 a	4835 a
	REM+TOR	1322 a	7316 ab
	CONT	21653 b	14517 b
Fall	MAT+REM	1327 a	1049 a
	MAT	790 a	2773 a
	REM+TOR	11171 b	10665 ab
	CONT	19689 b	17370 b

[1] Within a season of application, means followed by different letters are significantly different at P<0.05.

A one-way ANOVA was conducted to determine the effect of season of application within each treatment on mean huisache stem density (Table 18). For huisache at the Bush Ranch, season of application had no significant effect on stem density for MAT+REM ($F(2,9) = 0.75$, $p = .4991$), MAT ($F(2,9) = 4.08$, $p = .0547$), or CONT ($F(2,9) = 0.86$, $p = .4563$), but did have a significant effect for REM+TOR ($F(2,9) = 7.28$, $p = .0132$). Season of application had a significant effect on stem density at the Hitchcock Ranch for MAT+REM ($F(2,9) = 14.75$, $p = .0014$) and MAT ($F(2,9) =$

4.44, *p* = .0456), but did not have a significant effect for REM+TOR (F(2,9) = 3.68, *p* = .0678) or CONT (F(2,9) = 0.36, *p* = .7050).

Table 18. Effect of season of application on mean huisache stem density within each treatment.

Treatment	Season of Application	Site	
		Bush Ranch	Hitchcock Ranch
		------------ stems ha^{-1}-----------	
MAT+REM	Spring	3231 a[1]	35 a
	Summer	1953 a	3498 b
	Fall	1327 a	1049 a
MAT	Spring	4193 a	1076 a
	Summer	2056 ab	4835 b
	Fall	790 b	2773 ab
REM+TOR	Spring	2315 a	1775 a
	Summer	1322 a	4316 a
	Fall	11171 b	10665 a
CONT	Spring	12950 a	18147 a
	Summer	21653 a	14517 a
	Fall	19689 a	17367 a

[1] Within a treatment, means followed by different letters are significantly different at P<0.05.

Time-series graphs were created for percent change in mean horizontal huisache canopy area per living plant by treatment for each season of application for both sites (Figures 12 and 13). The data for creating these graphs are found in Appendix E. Points in time are expressed as days after treatment (DAT). In these plots, the higher rate of huisache stem density recovery with fall-applied REM+TOR compared to that of fall-applied MAT+REM and MAT is apparent.

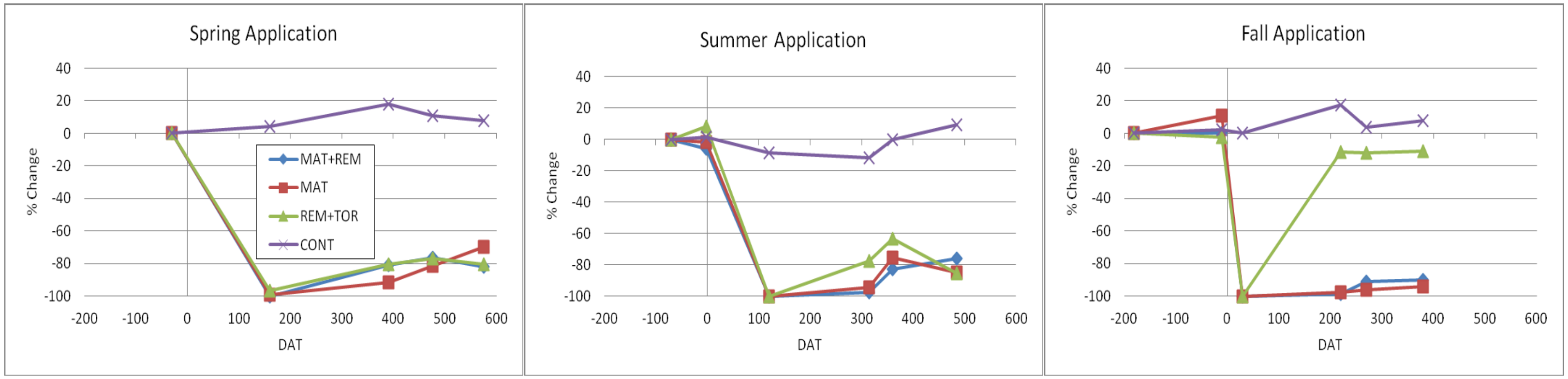

Figure 12. Time-series plots of percent change in mean huisache stem density at Bush Ranch

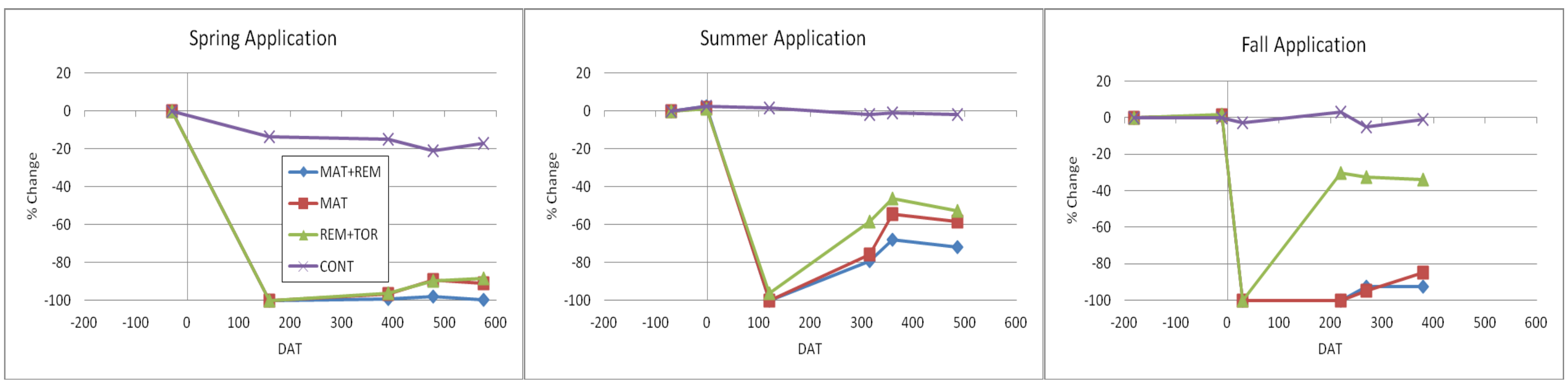

Figure 13. Time-series plots of percent change in mean huisache stem density at Hitchcock Ranch

Ground Cover Response

Forb Cover. Post-treatment forb cover values obtained at the end of the growing season in 2011 ranged from 0 to 10.5% at the Bush Ranch and from 0 to 6.8% at the Hitchcock Ranch (Table 19). A two-way ANOVA of forb cover at the Bush Ranch showed that there were main effects of both season of application ($F(2,36) = 3.79$, $p = .0321$) and treatment ($F(3,36) = 25.00$, $p < .0001$), as well as a significant interaction between season of application and treatment ($F(6,36) = 3.35$, $p = .0101$). The two-way ANOVA of forb cover at the Hitchcock Ranch showed that there was no significant main effect of season of application ($F(2,36) = 1.14$, $p = .3322$) or treatment ($F(3,36) = 0.45$, $p = .7186$), nor was there a significant interaction between two ($F(6,36) = 0.89$, $p = .5110$).

Table 19. Effect of season of application and treatment on mean forb cover.

Season of Application	Treatment	Site: Bush Ranch	Site: Hitchcock Ranch
		------------------% cover-----------------	
Spring	MAT+REM	0.0 a[1]	0.0 a
Spring	MAT	0.3 a	0.0 a
Spring	REM+TOR	0.5 a	0.0 a
Spring	CONT	4.5 ab	3.0 a
Summer	MAT+REM	3.5 ab	0.0 a
Summer	MAT	0.5 a	0.3 a
Summer	REM+TOR	0.3 a	0.5 a
Summer	CONT	6.0 bc	2.5 a
Fall	MAT+REM	0.0 a	3.8 a
Fall	MAT	0.3 a	6.8 a
Fall	REM+TOR	2.8 ab	0.5 a
Fall	CONT	10.5 c	0.8 a

[1] Within a column, means followed by different letters are significantly different at P<0.05.

A one-way ANOVA was conducted to determine the effect of herbicide treatment within each season of application on forb cover (Table 20). For the Bush Ranch, treatment had a significant effect on forb cover for the spring ($F(3,12) = 11.67$, $p = .0007$), summer ($F(3,12) = 8.35$, $p = .0029$), and fall ($F(3,12) = 11.29$, $p = .0008$), applications. Treatment had no significant effect on forb cover at the Hitchcock Ranch for the spring ($F(3,12) = 1.26$, $p = .3332$), summer ($F(3,12) = 1.92$, $p =.1809$), and fall ($F(3,12) = 0.62$, $p = .6144$) applications.

Table 20. Effect of treatment on mean forb cover within each season of application.

Season of Application	Treatment	Site: Bush Ranch	Site: Hitchcock Ranch
		------------ % cover -----------	
Spring	MAT+REM	0.0 a[1]	0.0 a
	MAT	0.3 a	0.0 a
	REM+TOR	0.5 a	0.0 a
	CONT	4.5 b	3.0 a
Summer	MAT+REM	3.5 ab	0.0 a
	MAT	0.5 a	0.3 a
	REM+TOR	0.3 a	0.5 a
	CONT	6.0 b	2.5 a
Fall	MAT+REM	0.0 a	3.8 a
	MAT	0.3 a	6.8 a
	REM+TOR	2.8 a	0.5 a
	CONT	10.5 b	0.8 a

[1] Within a season of application, means followed by different letters are significantly different at P<0.05.

A one-way ANOVA was conducted to determine the effect of season of application within each treatment on mean forb cover (Table 21). At the Bush Ranch, season of application had a significant effect on forb cover for MAT+REM ($F(2,9) = 5.07$, $p = .0335$) and REM+TOR ($F(2,9) = 4.71$, $p = .0399$), although Tukey's HSD did not yield any significant differences among means, but did not have a significant effect for MAT ($F(2,9) = 0.17$, $p = .8490$) or CONT ($F(2,9) = 3.02$, $p = .0988$). Season of application did not have a significant effect on forb cover at the Hitchcock Ranch for MAT+REM ($F(2,9) = 1.00$, $p = .4053$), MAT ($F(2,9) = 1.06$, $p = .3848$), REM+TOR ($F(2,9) = 0.50$, $p = .6224$) or CONT ($F(2,9) = 0.43$, $p = .6607$).

Table 21. Effect of season of application on mean forb cover within each treatment.

Treatment	Season of Application	Site	
		Bush Ranch	Hitchcock Ranch
		------------ % cover -----------	
MAT+REM	Spring	0.0 a[1]	0.0 a
	Summer	3.5 a	0.0 a
	Fall	0.0 a	3.8 a
MAT	Spring	0.3 a	0.0 a
	Summer	0.5 a	0.3 a
	Fall	0.3 a	6.8 a
REM+TOR	Spring	0.5 a	0.0 a
	Summer	0.3 a	0.5 a
	Fall	2.8 a	0.5 a
CONT	Spring	4.5 a	3.0 a
	Summer	6.0 a	2.5 a
	Fall	10.5 a	0.8 a

[1] Within a treatment, means followed by different letters are significantly different at $P<0.05$.

Grass Cover. Post-treatment grass cover values obtained at the end of the growing season in 2011 ranged from 9.8 to 29.3% at the Bush Ranch and from 14.0 to 49.3% at the Hitchcock Ranch. A two-way ANOVA of grass cover at the Bush Ranch showed that there a main effect of treatment (F(3,36) = 5.37, *p* = .0037) (Table 22), but no significant effect for season of application (F(2,36) = 1.06, *p* = .3576) or a significant interaction between season of application and treatment (F(6,36) = 1.44, *p* = .2266). The two-way ANOVA of grass cover at the Hitchcock Ranch also showed that there was a main effect of treatment (F(3,36) = 14.47, *p* < .0001), but no significant effect for season of application (F(2,36) = 1.23, *p* = .3055) or a significant interaction between season of application and treatment (F(6,36) = 1.20, *p* = .3267).

Table 22. Effect of treatment on mean grass cover.

Treatment	Bush Ranch	Hitchcock Ranch
	-------------------- stems ha^{-1}	--------------------
MAT+REM	27.2 a[1]	41.3 a
MAT	20.4 ab	42.3 a
REM+TOR	18.3 ab	39.2 a
CONT	12.2 b	17.8 b

[1] Means followed by different letters are significantly different at P<0.05.

A one-way ANOVA was conducted to determine the effect of herbicide treatment within each season of application on grass cover (Table 23). For the Bush Ranch, treatment had a significant effect on grass cover for the fall application (F(3,12) = 3.88, *p* = .0377), but not for the spring (F(3,12) = 2.62, *p* = .0988) or summer (F(3,12) = 1.95, *p* = .1756), applications. Treatment had a significant effect on grass cover at the

Hitchcock Ranch for the spring (F(3,12) = 21.00, $p < .0001$) and summer (F(3,12) = 10.36, $p = .0012$) applications, but not for the fall (F(3,12) = 0.75, $p = .5440$) application.

Table 23. Effect of treatment on mean grass cover within each season of application.

Season of Application	Treatment	Site	
		Bush Ranch	Hitchcock Ranch
		------------ % cover -----------	
Spring	MAT+REM	26.0 a[1]	42.8 a
	MAT	27.5 a	49.3 a
	REM+TOR	23.3 a	46.3 a
	CONT	10.5 a	14.0 b
Summer	MAT+REM	26.3 a	43.3 a
	MAT	24.8 a	44.3 a
	REM+TOR	15.3 a	36.8 a
	CONT	13.0 a	16.3 b
Fall	MAT+REM	29.3 a	38.0 a
	MAT	9.8 b	33.3 a
	REM+TOR	16.3 ab	34.5 a
	CONT	13.0 ab	23.0 a

[1] Within a season of application, means followed by different letters are significantly different at P<0.05.

A one-way ANOVA was conducted to determine the effect of season of application within each treatment on mean grass cover (Table 24). At the Bush Ranch, season of application did not have a significant effect on grass cover for MAT+REM (F(2,9) = 0.08, $p = .9197$), MAT (F(2,9) = 3.31, $p = .0836$), REM+TOR (F(2,9) = 2.48, $p = .1391$), or CONT (F(2,9) = 0.17, $p = .8437$). Season of application had a significant effect on forb cover at the Hitchcock Ranch for REM+TOR (F(2,9) =5.38, $p = .0291$), but not for MAT+REM (F(2,9) = 0.26, $p = .7755$), MAT (F(2,9) = 1.23, $p = .3376$) or CONT (F(2,9) = 1.17, $p = .3533$).

Table 24. Effect of season of application on mean grass cover within each treatment.

Treatment	Season of Application	Site	
		Bush Ranch	Hitchcock Ranch
		------------ % cover -----------	
MAT+REM	Spring	26.0 a[1]	42.8 a
	Summer	26.3 a	43.3 a
	Fall	29.3 a	38.0 a
MAT	Spring	27.5 a	49.3 a
	Summer	24.8 a	44.3 a
	Fall	9.8 a	33.3 a
REM+TOR	Spring	23.3 a	46.3 a
	Summer	15.3 a	36.8 ab
	Fall	16.3 a	34.5 b
CONT	Spring	10.5 a	14.0 a
	Summer	13.0 a	16.3 a
	Fall	13.0 a	23.0 a

[1] Within a treatment, means followed by different letters are significantly different at $P<0.05$.

Litter Cover. Litter cover values obtained in 2011 increased drastically from 2010 for all treatments, likely due to the extreme drought conditions present in 2011. Post-treatment litter cover values obtained at the end of the growing season in 2011 ranged from 66.3 to 88.5% at the Bush Ranch and from 38.0 to 57.3% at the Hitchcock Ranch. A two-way ANOVA of litter cover at the Bush Ranch did not reveal a significant main effect of treatment ($F(3,36) = 2.31$, $p = .0929$) or season of application ($F(2,36) = 0.49$, $p = .6138$), nor was there a significant interaction between season of application and treatment ($F(6,36) = 1.97$, $p = .0962$). The two-way ANOVA of litter cover at the Hitchcock Ranch also showed no significant main effect of treatment ($F(3,36) = .88$, $p = .4631$), season of application ($F(2,36) = 0.36$, $p = .6984$), or a significant interaction between season of application and treatment (F(6,36) = 1.00, p = .4396).

A one-way ANOVA was conducted to determine the effect of herbicide treatment within each season of application on litter cover. For the Bush Ranch, treatment had no significant effect on litter cover for the spring (F(3,12) = 0.90, p = .4698), summer (F(3,12) = 2.18, p = .1429), or fall (F(3,12) = 3.14, p = .0652), applications. Treatment also had no significant effect on litter cover at the Hitchcock Ranch for the spring (F(3,12) = 1.50, p = .2653), summer (F(3,12) = 0.50, p =.6921), or fall (F(3,12) = 1.04, p = .4117) applications.

A one-way ANOVA was also conducted to determine the effect of season of application within each treatment on mean litter cover. At the Bush Ranch, season of application did not have a significant effect on litter cover for MAT+REM (F(2,9) = 0.29, p = .7532), MAT (F(2,9) = 3.44, p = .0779), REM+TOR (F(2,9) = 1.85, p = .2123), or CONT (F(2,9) = 0.94, p = .4262). Season of application also had no significant effect on litter cover at the Hitchcock Ranch for MAT+REM (F(2,9) = 1.58, p = .2585), MAT (F(2,9) = 0.14, p = .8741), REM+TOR (F(2,9) = 3.37, p = .0811), or CONT (F(2,9) = 0.72, p = .5140).

Bare Ground. Post-treatment percent bare ground values obtained at the end of the growing season in 2011 ranged from 0.8 to 5.0% at the Bush Ranch and from 0 to 45.0% at the Hitchcock Ranch. A two-way ANOVA of bare ground values at the Bush Ranch did not reveal a significant main effect of treatment (F(3,36) = 2.66, p = .0626) or season of application (F(2,36) = 2.11, p = .1361), nor was there a significant interaction between season of application and treatment (F(6,36) = 1.70, p = .1494). The two-way ANOVA of bare ground at the Hitchcock Ranch showed that there was a significant main effect of treatment (F(3,36) = 3.14, p = .0369) (Table 25), but not a significant main effect of season of application (F(2,36) = 0.57, p = .5723), or a significant interaction between season of application and treatment (F(6,36) = 1.23, p = .3137).

Table 25. Effect of treatment on percent bare ground at Hitchcock Ranch.

Treatment	Bare Ground
	%
MAT+REM	8.4 a[1]
MAT	14.5 ab
REM+TOR	10.7 ab
CONT	30.8 b

[1] Means followed by different letters are significantly different at P<0.05.

A one-way ANOVA was conducted to determine the effect of herbicide treatment within each season of application on bare ground. For the Bush Ranch, treatment had no significant effect on bare ground for the spring (F(3,12) = 2.31, p = .1284), summer (F(3,12) = 1.87, p = .1883), or fall (F(3,12) = 1.92, p = .1797), applications. Treatment had no significant effect on bare ground at the Hitchcock Ranch for the summer (F(3,12) = 0.72, p = .5608 and fall (F(3,12) = 0.03, p =.9940) applications, but did yield a significant effect on bare ground for the spring (F(3,12) = 7.37, p = .0046) application (Table 26).

Table 26. Effect of spring-applied treatment on percent bare ground at Hitchcock Ranch.

Treatment	Bare Ground
	%
MAT+REM	0.0 a[1]
MAT	7.0 a
REM+TOR	0.0 a
CONT	45.0 b

[1] Means followed by different letters are significantly different at P<0.05.

A one-way ANOVA was also conducted to determine the effect of season of application within each treatment on bare ground. At the Bush Ranch, season of application did not have a significant effect on bare ground for MAT+REM ($F(2,9) = 1.63$, $p = .2485$), MAT ($F(2,9) = 3.45$, $p = .0771$), REM+TOR ($F(2,9) = 0.63$, $p = .5556$), or CONT ($F(2,9) = 0.69$, $p = .5252$). Season of application had no significant effect on bare ground at the Hitchcock Ranch for MAT+REM ($F(2,9) = 1.17$, $p = .3528$), MAT ($F(2,9) = 0.49$, $p = .6303$), or CONT ($F(2,9) = 0.85$, $p = .4592$), but did have a significant effect for REM+TOR ($F(2,9) = 10.82$, $p = .0040$) (Table 27).

Table 27. Effect of season of application of REM+TOR on percent bare ground for at Hitchcock Ranch.

Season of Application	Bare Ground
	%
Spring	0.5 a[1]
Summer	10.0 ab
Fall	21.5 b

[1] Means followed by different letters are significantly different at P<0.05.

CHAPTER VI

DISCUSSION

This investigation revealed that herbicide treatment and season of application significantly affect the growth and survivorship of *A. farnesiana* and herbaceous abundance. In addition, there were significant interactive effects between treatment and season of application.

Herbicide Treatment

Herbicide treatment had a significant effect on apparent huisache mortality at both sites. On the Wyick fine sandy loam at the Bush Ranch, there were no significant differences among treatments for the spring or summer herbicide applications, but both the MAT+REM and MAT treatments provided higher huisache control (78.2 and 77.3% mortality) than the REM+TOR treatment (3.8%) for the fall application. On the Weesatche fine sandy loam at the Hitchcock Ranch, fall-applied MAT+REM and MAT treatments both provided significantly greater control (77.9 and 77.2% mortality) than fall-applied REM+TOR treatments (29.2%). Also at the Hitchcock Ranch, spring and summer applied MAT+REM treatments provided greater control (98.7 and 48.8% mortality) than spring and summer applied MAT (72.7 and 16.1%) or REM+TOR (70.2 and 14.4%) treatments.

Post-treatment huisache canopy area was also significantly affected by herbicide treatment. At both sites, huisache canopies were significantly reduced by fall-applied MAT+REM (0.18 m^2 at Bush, 0.09 m^2 at Hitchcock) and MAT (0.06 m^2 at Bush, 0.15

m^2 at Hitchcock) treatments than fall-applied REM+TOR treatments (1.73 m^2 at Bush, 1.09 m^2 at Hitchcock). However, no significant differences in post-treatment huisache canopy area existed among the three herbicide treatments for the spring and summer applications at either site.

Herbicide treatment had a significant effect on post-treatment huisache stem density at the Bush Ranch. Fall-applied MAT+REM and MAT treatments resulted in significantly lower huisache stem densities (1327 and 790 stems ha^{-1}) than fall-applied REM+TOR treatments (11170 stems ha^{-1}). There were no significant differences in post-treatment huisache stem densities among the three herbicide treatments for the spring or summer applications at the Bush Ranch or for any of the applications at the Hitchcock Ranch.

Data from Bovey et al. (1981) of canopy reductions 3 to 6 months after foliar treatments with several different herbicides on huisache grown in a greenhouse suggest that the majority of control offered by REM+TOR may be provided by picloram. Picloram at a rate of 0.14 kg ha^{-1} resulted in greater canopy reductions (94%) than an ester formulation of triclopyr at rates of 0.14, 0.28, 0.56, 1.12, and 4.48 kg ha^{-1} (36, 50, 77, 89, and 90% canopy reductions) (Bovey et al. 1981). Additionally, Bovey et al. (1979) found that picloram alone at a rate of 1.12 kg ha^{-1} resulted in greater canopy reductions (98%) than triclopyr at rates of 1.12 and 2.24 kg ha^{-1} (56 and 78% canopy reductions) 15 weeks after treatment of greenhouse-grown huisache. Data from Bovey et al. (1981) showed that the combination of picloram and triclopyr at rates of 0.07 + 0.07, 0.14 + 0.14, 0.28 + 0.28, and 0.56 + 0.56 kg ha^{-1} resulted in greater huisache canopy reductions (4, 74, 99, and 99%) than triclopyr alone at rates of 0.14, 0.28, 0.56 kg ha^{-1} (36, 50, and 77% reductions), but was not more effective than picloram alone at the same three rates (74, 99, and 100% canopy reductions). Huisache has been observed to more readily absorb picloram than triclopyr applied at the same rate. Bovey et al. (1979) reported greater concentrations of picloram in leaves of huisache at 3, 10, and 30 DAT (41, 219, and 41 μg g^{-1} tissue) than triclopyr (7, 7, and 1 μg g^{-1}) when each herbicide was applied at a rate of 1.12 kg ha^{-1}. Herbicide concentrations in huisache stem tissues at 3, 10, and 30 DAT were also higher for picloram (6, 5, and 12 μg g^{-1}) than for triclopyr (3, 3, and 4 μg g^{-1}) when each were applied at 1.12 kg ha^{-1} (Bovey et al. 1979). These data may necessitate examining combinations of aminocyclopyrachlor and picloram for huisache control in future research. The data from this study suggests that the addition of triclopyr to aminocyclopyrachlor may be advantageous as it frequently resulted in increased levels of huisache control than aminocyclopyrachlor alone at a 50% higher rate. The 1:1 combination of triclopyr and picloram has been shown to be synergistic on the control of honey mesquite and whitebrush (*Aloysia gratissima* (Gillies &Hook.) Troncoso) and may be beneficial on sites with more diverse woody plant communities (Bovey et al. 1981; Jacoby and Meadors 1983).

Overall, herbicide treatments did not have many significant effects on herbaceous ground cover, perhaps due to the influence of extreme drought conditions in 2011. However, herbicide treatments yielded a few significant effects. Forb cover at the Bush Ranch was generally significantly higher in the untreated control plots (4.5 to 10.5%) than for any of the three herbicide treatments (0.0 to 3.5%), while forb cover at the

Hitchcock Ranch was unaffected by treatment. Grass cover at the Bush Ranch in fall-applied MAT+REM treatments was significantly higher (29.3%) than fall applied MAT treatments (9.8%). In all other instances, grass cover was not affected by treatment at either site. Likewise, herbicide treatments also had no significant effects on litter cover at either site. The percentage of bare ground was significantly lower at the Hitchcock Ranch for the three spring-applied herbicide treatments (0.0 to 7.0%) when compared to the spring control plots (45.0%), possibly due to the longer amount of time in the growing season for vegetation to recover following spring applications.

Season of Application

Season of application had a significant effect on huisache apparent mortality at both sites. At the Bush Ranch, there were no significant differences among seasons of application for the MAT+REM or MAT treatments, but there was a significant difference in huisache mortality between the spring (55.6%) and fall (3.8%) applications for the REM+TOR treatment. At the Hitchcock Ranch, huisache mortality for the MAT+REM treatment was significantly higher in the spring-applied plots (98.7%) versus the summer-applied plots (49.8%). For the MAT treatment, the spring and fall-applications exhibited higher huisache mortality (72.7 and 77.2%) than the summer application (16.1%). The spring-applied treatment of REM+TOR exhibited significantly higher rates of huisache mortality (70.2%) than the summer (14.4%) or fall (29.2%) applications. All three herbicide treatments applied during the summer at the Hitchcock Ranch exhibited an unusual decrease in huisache control that was not observed at the Bush Ranch. The reason for this decrease in control is unknown but may be potentially attributed to the presence of heavy dew at the time of application or a slight difference in precipitation (approximately 25-mm) in the two-week period prior to application. Kogan and Zuniga (2001) observed that dew could have an effect on the efficacy of glyphosate treatments, however their results indicate that at the spray volume used in this study (140 L ha^{-1}), dew would have likely have little effect on herbicide efficacy. This decreased level of control offered by summer applications at this site could also be due to potentially decreased photosynthetic activity of huisache plants due to water stress during the time of summer herbicide application. Data from Meyer (1977) on honey mesquite indicates that increasing water stress and the resulting decrease in photosynthetic activity tend to result in decreased chemical control. The research plots at the Hitchcock Ranch were much more sheltered from wind by larger trees at the perimeter of the site, potentially resulting in increased heat loading of huisache plants at this site versus those found at the Bush Ranch site.

For post-treatment huisache canopy area, huisache at the Bush Ranch treated with REM+TOR in the fall had significantly larger canopies (1.73 m^2) than those treated in the spring (0.54 m^2) or summer (0.43 m^2). At the Hitchcock Ranch, huisache in plots treated in the summer with MAT+REM and MAT exhibited larger huisache canopies (0.60 and 0.60 m^2) than spring (0.00 and 0.13 m^2) or fall (0.09 and 0.15 m^2) applications.

Season of application had a significant effect on post-treatment huisache stem densities at both sites. At the Bush Ranch, plots treated with MAT in the spring had significantly higher post-treatment stem densities (4193 stems ha^{-1}) than those treated in the fall (790 stems ha^{-1}). Plots that received REM+TOR in the fall exhibited significantly higher stem densities (11170 stems ha^{-1}) than those treated in the spring (2315 stems ha^{-1}) or summer (1322 stems ha^{-1}). At the Hitchcock Ranch, spring and fall-applied MAT+REM plots exhibited significantly lower post-treatment stem densities (35 and 1049 stems ha^{-1}) than those applied in the summer (3498 stems ha^{-1}). Spring-applied MAT plots exhibited significantly lower post-treatment huisache stem densities (1076 stems ha^{-1}) than summer-applied plots (4835 stems ha^{-1}). Post-treatment stem densities in REM+TOR treated plots were highly variable, yet not significantly different among seasons.

Bovey et al. (1970) found that applications of treatments of picloram were most effective when applied in May, June, July, and October. Likewise, McGinty et al. (2010) and Pestman (2011) recommend applications in spring or fall. The results of this study support these findings in regard to the spring application of herbicide treatments, where all three treatments provided effective huisache control. However, October application of the mixture of REM+TOR resulted in significantly lower levels of control at both sites. This decrease in control is partially supported by the findings of Bovey et al. (1972), where huisache control also decreased from October applications of picloram plus 2, 4, 5-T. This decrease in control of huisache by fall applied treatments was not observed in the treatments containing aminocyclopyrachlor with the exception of the fall application of MAT at the Hitchcock Ranch. In regard to summer applications of herbicide, the results of this study are inconclusive due to the inconsistent response of huisache to summer applications between the two sites.

Season of application had very little effect on post-treatment herbaceous ground cover. Post-treatment forb cover was higher in summer-applied MAT+REM plots at the Bush Ranch (3.5%) than that of spring or summer-applied plots (0.0 and 0.0%). Grass cover was significantly higher following spring applications of REM+TOR at the Hitchcock Ranch (46.3%) than that of fall applications (34.5%). Season of application had no other significant effects on post-treatment forb, grass, litter, or bare ground cover at either site.

Interaction Between Treatment and Season of Application

There was a significant interaction between treatment and season of application on apparent huisache mortality at both sites, as well as a significant interaction between the two effects on huisache canopy area at the Bush Ranch. At both sites, fall applications had a different effect on REM+TOR than it did on MAT+REM or MAT. At the Bush Ranch, season of application did not have an effect on huisache mortality or post-treatment canopy area for MAT+REM or MAT, while mortality was significantly lower and mean canopy area was higher for REM+TOR in fall-applied plots compared to spring or summer applications. At the Hitchcock Ranch, the trend in huisache mortality was similar among the three treatments for the spring and summer applications, but the fall application of REM+TOR saw a decreased level of huisache control that was not observed in fall-applied MAT+REM or MAT treatments.

CHAPTER VII

CONCLUSIONS

Huisache is an aggressive woody invader of range and pastureland in south Texas. Previous chemical control methods have offered effective temporary canopy reduction, but limited permanent control of huisache. The purpose of this study was to evaluate the effectiveness of different herbicide mixtures and seasons of application on the control of huisache in south Texas. Results demonstrate that the recommended herbicide treatment included in this study frequently results in less effective huisache control than that provided by either of the treatments containing aminocyclopyrachlor in terms of huisache mortality, huisache canopy reduction, and reduction in huisache stem density. Results also reveal that spring applications of herbicide treatments generally resulted in greater huisache mortality, huisache canopy reduction, and reduction in huisache stem density.

Of the herbicide treatments and seasons of application examined, the broadcast application in the spring of 0.210 kg a.i. ha^{-1} of aminocyclopyrachlor mixed with 0.420 kg a.e. ha^{-1} of triclopyr consistently provided the best combination of results for the control of huisache. For sites invaded by huisache located in close proximity to areas where susceptible crops are grown, the application of aminocyclopyrachlor plus triclopyr or aminocyclopyrachlor alone at the higher rate in the fall after those crops are harvested may be more desirable in order to avoid potential non-target injury while still providing acceptable levels of huisache control.

This study was conducted on huisache that had been repeatedly mowed for several years in order to suppress woody plant canopy cover and maintain range forage production, resulting in high numbers of stems per plant. Data from Jacoby et al. (1990) on chemical control of honey mesquite in relation to stem numbers indicated that the efficacy of herbicide treatments decreased as the number of stems per plant increased. Future research will need to be conducted to assess the efficacy of these herbicide treatments on huisache with fewer stems as well as on plants that have been allowed to form larger and denser canopies. Additionally, further study will be necessary to identify the specific environmental criteria and factors within the huisache plant that most influence the ability of these herbicides to effectively control huisache. The data from this study from the Bush Ranch site suggests that treatments with aminocyclopyrachlor may have reduce the abundance of dicot species, but further research will need to be conducted to identify the effect of aminocyclopyrachlor on the herbaceous community, which this study was largely unable to provide due to extreme drought conditions.

LITERATURE CITED

Ashton, F.M, and A.S. Crafts. 1981. Mode of action of herbicides. 2nd ed.. New York, NY, USA: John Wiley and Sons. 525 p.

Bontrager, O.E., C.J. Scifres, and D.L. Drawe. 1979. Huisache control by power grubbing. *Journal of Range Management*. 32: 185-188.

Bovey, R.W., F.S. Davis, and M.G. Merkle. 1967. Distribution of picloram in huisache after foliar and soil applications. *Weeds*. 15: 245-249.

Bovey, R.W., F.S. Davis, and H.L. Morton. 1968. Herbicide combinations for woody plant control. *Weeds.* 16: 332-335

Bovey, R.W., H.L. Morton, J.R. Baur, J.D. Diaz-Colon, C.C. Dowler, and S.K. Lehman. 1969. Granular herbicides for woody plant control. *Weed Science*. 17:538-541.

Bovey, R.W., J.R. Baur, and H.L. Morton. 1970. Control of huisache and associated woody species in south Texas. *Journal of Range Management*. 20: 577-580.

Bovey, R.W., R.H. Haas, and R.E. Meyer. 1972. Daily and seasonal response of huisache and macartney rose to herbicides. *Weed Science*. 20: 577-580.

Bovey, R.W., and R.E. Meyer. 1978. Control of huisache with soil applied herbicides. *Journal of Range Management*. 31:179-182.

Bovey, R.W., M.L. Ketchersid, and M.G. Merkle. 1979. Distribution of triclopyr and picloram in huisache (*Acacia farnesiana*). *Weed Science*. 27: 527-531.

Bovey, R.W., R.E. Meyer, and J.R. Baur. 1981. Potential herbicides for brush control. *Journal of Range Management.* 34: 144-148.

Box, T.W., and R.S. White. 1969. Fall and winter burning of south Texas brush ranges. *Journal of Range Management*. 22: 373-376.

Bush, J.K., and O.W. Van Auken. 1986. Light requirements of *Acacia smallii* and *Celtis laevigata* in relation to secondary succession of floodplains of south Texas. *The American Midland Naturalist.* 115: 118-122.

Bush, J.K., and O.W. Van Auken. 1987. Some demographic and allometric characteristics of *Acacia smallii* (Mimosaceae) in successional communities. *Madrono*. 34: 250-259.

Bush, J.K., F.A. Richter, and O.W. Van Auken. 2006. Two decades of vegetation change on terraces of a south Texas river. *Journal of the Torrey Botanical Society*. 133: 280-288.

Carter, M.G. 1958. Reclaiming Texas brushland range. *Journal of Range Management*. 11: 1-5.

Clarke, D.H., D.S. Seigler, and J.E. Ebinger. 1989. *Acacia farnesiana* (Fabaceae: Mimosoideae) and related species from Mexico, the southwestern U.S., and the Caribbean. *Systematic Botany*. 14: 549-564.

Cobb, A. 1992. Herbicides and plant physiology, 1st ed. London, U.K: Chapman and Hall. 176 p.

Darrow, R.A., L. Reyes, and R.A. Hall. 1953. Chemical control of huisache. College Station, TX, USA. Texas Agricultural Experiment Station. Progress Report 1560. 3 p.

Devine, M.D., S.O. Duke, and C. Fedtke. 1993. Physiology of herbicide action. Englewood Cliffs, N.J., USA: Prentice Hall. 441 p.

DuPont. 2009. DuPont DPX-MAT28 herbicide. Technical Bulletin. DuPont Crop Protection. Willminton, DE, USA. 8 p.

Ebinger, J.E., D.S. Seigler, and H.D. Clarke. 2002. Notes on the segregates of *Acacia farnesiana* (L.) Willd. (Fabaceae: Mimosoideae) and related species in North America. *The Southwestern Naturalist*. 47: 86-91.

Hart, C.R., B. Rector, C.W. Hanselka, R.K. Lyons, and W.A. McGinty. 2008. Brush and weeds of Texas rangelands. College Station, TX, USA. Texas A&M Press. 203 p.

Isely, D. 1969. Legumes of the United States: 1. Native *Acacia*. *Sida.* 3: 365-386.

Jacoby, P.W. and C.H. Meadors. 1983. Triclopyr for control of honey mesquite (*Prosopis juliflora* var. *glandulosa*). *Weed Science*. 31: 681-685.

Jacoby, P.W., R.T. Ansley, C.H. Meadors, and C.T. Cuomo. 1990. Control of honey mesquite with herbicides: influence of stem number. *Journal of Range Management*. 43: 36-38.

Johnson, H.B., H.W. Polley, and H.S. Mayeux. 1995. Nitrogen accumulation tracks carbon in multispecies system under elevated CO^2. Bulletin of the Ecological Society of America. 76: 346.

Jurado, E., J. Navar, H. Villalon, and M. Pando. 2001. Germination associated with season and sunlight for Tamaulipan thornscrub plants in north-eastern Mexico. *Journal of Arid Environments*. 49: 833-841.

Kogan, M. and M. Zuniga. 2001. Dew and spray volume effect on glyphosate efficacy. *Weed Technology*. 15: 590-593.

Lohstroh, R.J., and O.W. Van Auken. 1987. Comparison of canopy position and other factors on seedling growth in *Acacia smallii. The Texas Journal of Science*. 39: 233-239.

McGinty, A., J. Ansley, W. Hamilton, C. Hart, L. Redmon, and R. Lyons. 2010. Chemical weed and brush control: Suggestions for rangeland. College Station, TX, USA. Agrilife Extension. B-1466. 36 p.

Meyer, R.E., R. W. Bovey, T.E. Riley, and T.O. Flynt. 1976. Seasonal response of macartney rose and huisache to herbicides. *Journal of Range Management*. 29: 157-160.

Meyer, R.E. 1976. Season response of honey mesquite to herbicides. College Station, TX, USA. Texas Agricultural Experiment Station Bulletin 1174. 14 p.

Meyer, R.E., and R.W. Bovey. 1982. Establishment of honey mesquite and huisache on a native pasture. *Journal of Range Management*. 35: 548-550.

Major Land Resource Area Explorer. NRCS. 2011. Available at: http://www.cei.psu.edu/mlra/ (accessed 15 January 2011).

Pestman, 2011. Online weed and brush control advisor. Available at: http://www.pestman.tamu.edu. (accessed 16 November 2011).

Polley, H.W., H.B. Johnson, and H.S. Mayeux. 1997. Leaf physiology, production, water use, and nitrogen dynamics of the grassland invader *Acacia smallii* at elevated CO^2 concentrations. *Tree Physiology.* 17: 89-96.

Powell, J.T., and T.W. Box. 1967. Mechanical control and fertilization as brush management practices affect forage production in south Texas. *Journal of Range Management*. 20: 227-235.

Powell, J., T.W. Box, and C.V. Baker. 1972. Growth rate of sprouts after top removal of huisache (*Acacia farnesiana* (L.) Willd.) (*Leguminosae)* in south Texas. *The Southwestern Naturalist*. 17: 191-195.

Rasmussen, G.A., C.J. Scifres, and D.L. Drawe. 1983. Huisache growth, browse quality and use following burning. *Journal of Range Management*. 36:337-342.

Scifres, C.J.. 1974. Salient aspects of huisache seed germination. *The Southwestern Naturalist*. 18: 383-392.

Scifres, C.J.. 1980. Brush Management. College Station, TX, USA: Texas A&M University Press. 360 p.

Scifres, C.J., J.L. Mutz, D.L. Drawe. 1982a. Ecology and management of huisache on the Texas coastal prairie. College Station, TX, USA: Texas Agricultural Experiment Station. Bulletin-1408.

Scifres, C.J., J.L. Mutz, R.E. Whitson, and D.L. Drawe. 1982b. Interrelations of huisache canopy cover with range forage on the coastal prairie. *Journal of Range Management*. 35: 558-562.

Scifres, C.J., and W.T. Hamilton. 1993. Prescribed burning for brushland management: the south Texas example. College Station, TX, USA: Texas A&M University Press. 246 p.

Smith, H.N., and C.A. Rechenthin. 1964. Grassland restoration. The Texas brush problem. U.S. Department of Agriculture. Soil Conservation Service Bulletin 4-19114. 17 p.

Southern Regional Climate Center. 2011a. Climate normals for Goliad, TX, Station ID 413618. Available at: http://www.srcc.lsu.edu/stations/index.php?action=metadata&network_station_id=413618 (accessed 15 December 2011).

Southern Regional Climate Center. 2011b. Climate normals for Beeville, TX, Station ID 410639. Available at: http://www.srcc.lsu.edu/stations/index.php?action=metadata&network_station_id=410639 (accessed 15 December 2011).

Stubbendieck, J., S.L. Hatch, and L.M. Landholt. 2003. North American wildland plants. Lincoln, NE, USA. University of Nebraska Press. 501 p.

Van Auken, O.W., and J.K. Bush. 1985. Secondary succession on terraces of the San Antonio River. *Torrey Botanical Club Bulletin*. 112: 158-166.

Van Auken, O.W., E.M. Gese, and K. Connors. 1985. Fertilization response of early and late successional species: *Acacia smallii* and *Celtis laevigata*. *Botanical Gazette*. 146: 564-569.

Vines, R.A. 1960. Trees, shrubs, and woody vines of the Southwest. Austin, TX, USA: University of Texas Press. 1104 p.

Vora, R.S. 1989. Seed germination characteristics of selected native plants of the lower Rio Grande Valley, Texas. *Journal of Range Management*. 42: 36-40.

Web Soil Survey. NRCS. 2011. Available at: http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx (accessed 15 January 2011).

APPENDIX A

MONTHLY PRECIPITATION AT RESEARCH SITES

Bush Ranch Monthly Precipitation (mm)

Month	2009	2010	2011	Mean
January	3.556	59.944	127.000	59.436
February	3.556	93.980	9.398	53.594
March	58.166	41.656	1.016	50.800
April	72.136	87.376	0.000	81.026
May	133.095	97.282	39.370	114.046
June	9.398	97.790	42.672	125.984
July	32.004	217.170	0.000	72.390
August	34.036	14.732	22.860	88.646
September	193.040	284.480	27.940	115.824
October	173.482	0.000	81.280	108.204
November	130.048	35.052		55.626
December	71.374	21.590		54.356
Annual Total	913.892	1051.052		979.932

Hitchcock Ranch Monthly Precipitation (mm)

Month	2009	2010	2011	Mean
January	3.302	74.170	70.610	49.280
February	1.270	122.94	5.840	46.740
March	52.070	36.320	2.790	48.260
April	29.972	129.540	0.000	68.070
May	39.878	62.740	20.070	88.650
June	21.844	96.010	25.400	106.430
July	12.446	215.900	0.000	68.330
August	26.67	13.720	12.700	76.710
September	166.116	269.490	20.320	109.220
October	224.025	0.760	0.000	91.440
November	132.588	53.086		50.80
December	76.708	9.652		46.4820
Annual Total	786.892	1084.326		850.392

APPENDIX B

MEAN APPARENT HUISACHE MORTALITY VALUES COLLECTED FALL 2011 BASED ON ALL INDIVIDUALS LOCATED WITHIN EACH PLOT

Season of Application	Treatment	Site: Bush Ranch	Site: Hitchcock Ranch
		-----% mortality-----	
Spring	MAT+REM	53.51	95.55
	MAT	58.12	70.87
	REM+TOR	53.07	66.86
	CONT	0.00	0.00
Summer	MAT+REM	65.27	46.68
	MAT	69.00	31.68
	REM+TOR	61.88	17.86
	CONT	0.00	0.00
Fall	MAT+REM	77.16	70.07
	MAT	78.52	78.27
	REM+TOR	7.16	22.30
	CONT	1.38	0.00

APPENDIX C

PRE AND POST-TREATMENT HUISACHE CANOPY AREA

BUSH RANCH

Season of Application	Treatment	--------2010-------- APR	JUL	OCT	NOV	--------2011-------- MAY	JUL	OCT
		---m^2---						
Spring	MAT+REM	1.38 a[1]	-	-	0.00 a	0.13 a	0.24 ab	0.54 a
Spring	MAT	1.25 a	-	-	0.04 a	0.05 a	0.24 ab	0.45 a
Spring	REM+TOR	1.08 a	-	-	0.08 a	0.14 a	0.31 ab	0.54 a
Spring	CONT	1.47 a	-	-	2.22 b	2.37 b	2.53 d	3.22 c
Summer	MAT+REM	1.60 a	1.70 a	-	0.00 a	0.01 a	0.12 ab	0.16 a
Summer	MAT	1.92 a	2.02 a	-	0.00 a	0.03 a	0.32 ab	0.41 a
Summer	REM+TOR	1.70 a	1.76 a	-	0.00 a	0.07 a	0.40 ab	0.42 a
Summer	CONT	1.77 a	1.97 a	-	1.92 b	1.99 b	2.23 d	3.16 c
Fall	MAT+REM	2.09 a	-	1.67 a	0.00 a	0.01 a	0.10 ab	0.18 a
Fall	MAT	1.60 a	-	1.47 a	0.00 a	0.01 a	0.03 a	0.06 a
Fall	REM+TOR	1.51 a	-	1.41 a	0.00 a	0.57 a	1.07 bc	1.73 b
Fall	CONT	1.73 a	-	1.39 a	1.60 b	1.70 b	1.73 cd	2.17 bc

[1] Within a column, means followed by different letters are significantly different at P<0.05.

HITCHCOCK RANCH

Season of Application	Treatment	2010 APR	2010 JUL	2010 OCT	2010 NOV	2011 MAY	2011 JUL	2011 NOV
		m²						
Spring	MAT+REM	1.39 a[1]	-	-	0.00 a	0.01 a	0.03 a	0.00 a
Spring	MAT	1.38 a	-	-	0.00 a	0.02 ab	0.06 a	0.13 a
Spring	REM+TOR	1.22 a	-	-	0.00 a	0.03 ab	0.21 ab	0.40 ab
Spring	CONT	1.33 a	-	-	1.57 b	1.94 c	2.21 c	2.30 c
Summer	MAT+REM	1.49 a	1.64a	-	0.00 a	0.08 ab	0.28 ab	0.60 ab
Summer	MAT	1.54 a	1.78 a	-	0.00 a	0.13 ab	0.28 ab	0.60 ab
Summer	REM+TOR	1.38 a	1.45 a	-	0.04 a	0.35 ab	0.80 ab	1.11 b
Summer	CONT	1.34 a	1.57 a	-	1.74 b	2.23 c	2.38 c	2.42 c
Fall	MAT+REM	1.22 a	-	1.23 a	0.00 a	0.00 a	0.02 a	0.09 a
Fall	MAT	1.62 a	-	1.62 a	0.00 a	0.00 a	0.04 a	0.15 a
Fall	REM+TOR	1.49 a	-	1.70 a	0.00 a	0.66 b	1.03 b	1.10 b
Fall	CONT	1.48 a	-	1.68 a	1.75 b	2.31 c	2.46 c	2.85 c

[1] Within a column, means followed by different letters are significantly different at P<0.05.

APPENDIX D

PRE AND POST-TREATMENT HUISACHE STEM DENSITIES

BUSH RANCH

Season of Application	Treatment	2010 APR	2010 JUL	2010 OCT	2010 NOV	2011 MAY	2011 JUL	2011 OCT
		stems ha^{-1}						
Spring	MAT+REM	17808 a[1]	-	-	0 a	3380 ab	4204 ab	3231 a
Spring	MAT	13974 a	-	-	148 a	1199 ab	2581 ab	4192 a
Spring	REM+TOR	11868 a	-	-	377 a	2313 ab	2736 ab	2315 a
Spring	CONT	11991 a	-	-	12485 b	14171 cd	13279 bc	12949 ab
Summer	MAT+REM	8133 a	7656 a	-	0 a	195 a	1412 a	1952 a
Summer	MAT	13575 a	13306 a	-	0 a	438 a	3352 ab	2055 a
Summer	REM+TOR	9226 a	9992 a	-	0 a	2083 ab	3387 ab	1322 a
Summer	CONT	19812 a	20118 a	-	18153 b	17497 cd	19753 c	21652 b
Fall	MAT+REM	13035 a	-	13054 a	0 a	156 a	1150 a	1327 a
Fall	MAT	12934 a	-	14008 a	0 a	322 a	505 a	790 a
Fall	REM+TOR	12538 a	-	12249 a	0 a	11071 bc	11066 abc	11170 ab
Fall	CONT	18300 a	-	18688 a	18330 b	21455 d	18992 c	19688 b

[1] Within a column, means followed by different letters are significantly different at $P<0.05$.

HITCHCOCK RANCH

Season of Application	Treatment	2010				2011		
		APR	JUL	OCT	NOV	MAY	JUL	NOV
		stems ha^{-1}						
Spring	MAT+REM	11114 a[1]	-	-	0 a	67 a	236 a	35 a
Spring	MAT	11850 a	-	-	0 a	410 ab	1282 ab	1076 ab
Spring	REM+TOR	15251 a	-	-	0 a	564 ab	1581 ab	1775 ab
Spring	CONT	21954 a	-	-	18930 b	18667 d	17316 d	18147 d
Summer	MAT+REM	12515 a	12816 a	-	0 a	2585 ab	4023 ab	3497 ab
Summer	MAT	11626 a	11808 a	-	0 a	2819 ab	5280 abc	4835 abc
Summer	REM+TOR	15462 a	15642 a	-	556 a	6419 abc	8306 abcd	7316 abc
Summer	CONT	14847 a	15161 a	-	15036 b	14514 cd	14676 cd	14516 cd
Fall	MAT+REM	14163 a	-	14362 a	0 a	0 a	1059 ab	1049 ab
Fall	MAT	18013 a	-	18250 a	0 a	0 a	915 ab	2772 ab
Fall	REM+TOR	17845 a	-	18200 a	0 a	12422 bcd	12074 bcd	10664 bcd
Fall	CONT	17505 a	-	17540 a	16998 b	18055 d	16656 d	17369 d

[1] Within a column, means followed by different letters are significantly different at P<0.05.

APPENDIX E

PRE AND POST-TREATMENT FORB COVER

BUSH RANCH

Season of Application	Treatment	2010				2011		
		APR	JUL	OCT	NOV	MAY	JUL	OCT
		% cover						
Spring	MAT+REM	28.50 ab[1]	-	-	1.00 c	0.25 a	0.00 a	0.00 a
Spring	MAT	24.00 ab	-	-	0.50 c	2.25 ab	0.00 a	0.25 a
Spring	REM+TOR	30.00 ab	-	-	0.50 c	1.00 ab	0.25 ab	0.50 a
Spring	CONT	28.00 ab	-	-	7.75 abc	5.50 ab	3.50 bc	4.50 ab
Summer	MAT+REM	41.00 a	28.00 a	-	3.00 bc	5.25 ab	1.50 abc	3.50 ab
Summer	MAT	16.25 b	30.25 a	-	2.25 c	3.00 ab	0.25 ab	0.50 a
Summer	REM+TOR	26.50 ab	27.00 a	-	0.50 c	1.75 ab	1.00 abc	0.25 a
Summer	CONT	17.75 ab	28.00 a	-	12.00 a	4.50 ab	2.50 abc	6.00 bc
Fall	MAT+REM	22.75 ab	-	15.50 a	2.75 bc	0.00 a	0.00 a	0.00 a
Fall	MAT	17.50 b	-	13.75 a	5.75 abc	0.75 a	0.00 a	0.25 a
Fall	REM+TOR	13.50 b	-	16.75 a	4.00 abc	2.75 ab	0.25 ab	2.75 ab
Fall	CONT	22.50 ab	-	22.00 a	11.50 ab	7.00 b	4.25 c	10.50 c

[1] Within a column, means followed by different letters are significantly different at $P<0.05$.

HITCHCOCK RANCH

Season of Application	Treatment	-------------------2010-----------------				-----------2011------------		
		APR	JUL	OCT	NOV	MAY	JUL	NOV
		---------------------------------------% cover---------------------------------						
Spring	MAT+REM	38.25 ab[1]	-	-	0.25 c	0.00 a	0.00 a	0.00 a
Spring	MAT	65.25 a	-	-	2.50 bc	0.25 a	0.25 a	0.00 a
Spring	REM+TOR	46.00 ab	-	-	0.50 c	0.25 a	0.00 a	0.00 a
Spring	CONT	52.25 ab	-	-	36.50 a	15.50 a	2.00 a	3.00 a
Summer	MAT+REM	22.25 b	21.25 a	-	4.50 bc	2.25 a	0.00 a	0.00 a
Summer	MAT	34.00 ab	32.75 a	-	32.75 ab	2.00 a	0.50 a	0.25 a
Summer	REM+TOR	42.50 ab	33.50 a	-	1.00 c	0.50 a	0.00 a	0.50 a
Summer	CONT	28.25 ab	23.25 a	-	20.25 abc	8.50 a	2.75 a	2.50 a
Fall	MAT+REM	26.75 ab	-	29.50 a	8.50 abc	4.75 a	4.75 a	3.75 a
Fall	MAT	35.50 ab	-	34.25 a	8.75 abc	4.50 a	7.00 a	6.75 a
Fall	REM+TOR	40.25 ab	-	41.00 a	8.75 abc	3.00 a	1.00 a	0.50 a
Fall	CONT	39.50 ab	-	28.25 a	18.25 abc	8.50 a	3.75 a	0.75 a

[1] Within a column, means followed by different letters are significantly different at $P<0.05$.

APPENDIX F

PRE AND POST-TREATMENT GRASS COVER

BUSH RANCH

Season of Application	Treatment	2010 APR	2010 JUL	2010 OCT	2010 NOV	2011 MAY	2011 JUL	2011 OCT
		% cover						
Spring	MAT+REM	24.50 a[1]	-	-	93.00 ab	85.00 a	46.75 a	26.25 a
Spring	MAT	35.00 a	-	-	89.50 abc	77.75 a	45.00 a	27.50 a
Spring	REM+TOR	24.25 a	-	-	90.50 abc	79.25 a	34.75 a	23.25 a
Spring	CONT	27.50 a	-	-	78.00 cd	76.25 a	24.75 a	10.50 a
Summer	MAT+REM	23.75 a	30.50 a	-	83.00 abcd	71.75 a	36.00 a	26.25 a
Summer	MAT	41.25 a	33.50 a	-	79.75 bcd	70.75 a	43.75 a	24.75 a
Summer	REM+TOR	31.75 a	35.50 a	-	95.50 a	81.00 a	51.75 a	15.25 a
Summer	CONT	33.75 a	30.50 a	-	79.50 bcd	76.25 a	34.25 a	13.00 a
Fall	MAT+REM	37.25 a	-	70.00 a	90.75 abc	81.25 a	58.25 a	29.25 a
Fall	MAT	27.50 a	-	67.75 a	87.75 abc	80.50 a	35.50 a	9.75 a
Fall	REM+TOR	43.00 a	-	68.75 a	87.78 abc	78.00 a	39.00 a	16.25 a
Fall	CONT	30.50 a	-	61.25 a	72.00 d	74.00 a	39.75 a	13.00 a

[1] Within a column, means followed by different letters are significantly different at P<0.05.

HITCHCOCK RANCH

Season of Application	Treatment	2010 APR	2010 JUL	2010 OCT	2010 NOV	2011 MAY	2011 JUL	2011 OCT
		% cover						
Spring	MAT+REM	30.00 a	-	-	98.50 a	54.00 ab	75.25 a	42.75 ab
Spring	MAT	10.75 a	-	-	90.25 a	60.50 ab	70.50 a	49.25 a
Spring	REM+TOR	31.50 a	-	-	98.50 a	37.25 ab	67.25 a	4.25 ab
Spring	CONT	17.00 a	-	-	46.75 a	31.50 ab	38.00 a	14.00 c
Summer	MAT+REM	42.75 a	52.25 a	-	80.75 a	70.50 a	67.75 a	43.25 ab
Summer	MAT	28.50 a	41.50 a	-	41.50 a	65.50 ab	64.75 a	44.25 ab
Summer	REM+TOR	24.00 a	37.00 a	-	79.25 a	64.25 ab	70.50 a	36.75 abc
Summer	CONT	29.75 a	42.50 a	-	62.50 a	26.75 b	36.25 a	16.25 c
Fall	MAT+REM	41.00 a	-	63.00 a	73.50 a	49.75 ab	55.75 a	38.00 abc
Fall	MAT	28.75 a	-	59.00 a	64.25 a	40.00 ab	50.25 a	33.25 abc
Fall	REM+TOR	29.50 a	-	51.25 a	80.25 a	54.25 ab	66.25 a	34.50 abc
Fall	CONT	29.25 a	-	68.75 a	70.50 a	40.75 ab	46.25 a	23.00 bc

[1] Within a column, means followed by different letters are significantly different at P<0.05.

APPENDIX G

PRE AND POST-TREATMENT WOODY PLANT GROUND COVER

BUSH RANCH

Season of Application	Treatment	2010 APR	2010 JUL	2010 OCT	2010 NOV	2011 MAY	2011 JUL	2011 OCT
		% cover						
Spring	MAT+REM	1.25 a[1]	-	-	1.00 a	0.25 a	0.00 a	0.00 a
Spring	MAT	1.50 a	-	-	0.00 a	1.00 a	0.00 a	0.00 a
Spring	REM+TOR	4.50 a	-	-	1.00 a	0.25 a	0.00 a	0.00 a
Spring	CONT	0.75 a	-	-	0.50 a	0.50 a	0.25 a	0.25 a
Summer	MAT+REM	1.25 a	0.00 a	-	0.00 a	0.50 a	0.00 a	0.00 a
Summer	MAT	2.75 a	0.00 a	-	0.50 a	0.50 a	0.00 a	0.00 a
Summer	REM+TOR	0.50 a	0.50 a	-	0.00 a	0.00 a	0.00 a	0.00 a
Summer	CONT	1.50 a	0.50 a	-	1.50 a	1.00 a	1.00 a	0.75 a
Fall	MAT+REM	3.00 a	-	0.25 a	0.00 a	0.00 a	0.00 a	0.00 a
Fall	MAT	2.50 a	-	0.50 a	0.00 a	0.00 a	0.25 a	0.00 a
Fall	REM+TOR	1.00 a	-	0.00 a	0.00 a	0.00 a	0.00 a	0.25 a
Fall	CONT	0.00 a	-	1.00 a	0.50 a	0.25 a	0.50 a	0.50 a

[1] Within a column, means followed by different letters are significantly different at $P<0.05$.

HITCHCOCK RANCH

Season of Application	Treatment	2010 APR	2010 JUL	2010 OCT	2010 NOV	2011 MAY	2011 JUL	2011 OCT
		% cover						
Spring	MAT+REM	2.00 a[1]	-	-	0.25 a	0.00 a	0.00 a	0.00 a
Spring	MAT	1.75 a	-	-	0.50 a	0.00 a	0.25 a	0.00 a
Spring	REM+TOR	4.25 a	-	-	0.00 a	0.00 a	0.00 a	0.00 a
Spring	CONT	3.75 a	-	-	0.50 a	0.50 a	0.25 a	0.50 a
Summer	MAT+REM	0.00 a	0.00 a	-	1.00 a	0.00 a	0.00 a	0.25 a
Summer	MAT	1.00 a	0.50 a	-	0.50 a	0.00 a	0.25 a	0.50 a
Summer	REM+TOR	0.50 a	1.50 a	-	0.50 a	0.25 a	0.50 a	0.25 a
Summer	CONT	0.00 a	0.00 a	-	0.50 a	0.75 a	0.25 a	0.75 a
Fall	MAT+REM	1.50 a	-	1.00 a	0.50 a	0.00 a	0.00 a	0.00 a
Fall	MAT	1.50 a	-	0.75 a	0.00 a	0.00 a	0.00 a	0.00 a
Fall	REM+TOR	1.00 a	-	1.25 a	0.00 a	0.00 a	0.50 a	0.25 a
Fall	CONT	1.00 a	-	0.50 a	0.50 a	0.50 a	0.50 a	0.75 a

[1] Within a column, means followed by different letters are significantly different at $P<0.05$.

APPENDIX H

PRE AND POST-TREATMENT LITTER COVER

BUSH RANCH

Season of Application	Treatment	2010				2011		
		APR	JUL	OCT	NOV	MAY	JUL	OCT
		% cover						
Spring	MAT+REM	29.00 a[1]	-	-	3.50 ab	13.75 a	50.75 a	73.00 a
Spring	MAT	33.25 a	-	-	2.00 b	14.50 a	50.50 a	70.50 a
Spring	REM+TOR	27.25 a	-	-	3.50 ab	18.50 a	61.25 a	69.75 a
Spring	CONT	37.50 a	-	-	9.00 ab	13.75 a	67.50 a	80.75 a
Summer	MAT+REM	16.75 a	19.00 a	-	6.00 ab	15.75 a	53.50 a	66.25 a
Summer	MAT	32.25 a	14.50 a	-	7.50 ab	18.25 a	48.00 a	69.75 a
Summer	REM+TOR	22.00 a	18.50 a	-	2.00 b	14.50 a	43.75 a	83.00 a
Summer	CONT	31.50 a	19.00 a	-	2.75 b	15.00 a	54.00 a	77.75 a
Fall	MAT+REM	25.25 a	-	7.75 a	4.50 ab	16.25 a	39.50 a	69.25 a
Fall	MAT	34.00 a	-	5.25 a	5.00 ab	15.25 a	60.75 a	88.50 a
Fall	REM+TOR	34.75 a	-	7.00 a	6.25 ab	17.25 a	57.00 a	79.25 a
Fall	CONT	36.50 a	-	4.50 a	10.50 a	13.75 a	51.50 a	72.00 a

[1] Within a column, means followed by different letters are significantly different at P<0.05.

HITCHCOCK RANCH

Season of Application	Treatment	2010 APR	2010 JUL	2010 OCT	2010 NOV	2011 MAY	2011 JUL	2011 OCT
		% cover						
Spring	MAT+REM	24.75 a[1]	-	-	0.75 a	46.00 ab	24.75 a	57.25 a
Spring	MAT	3.00 a	-	-	0.75 a	38.75 ab	27.50 a	43.75 a
Spring	REM+TOR	11.00 a	-	-	1.00 a	62.50 a	32.75 a	53.25 a
Spring	CONT	10.50 a	-	-	4.50 a	32.00 ab	38.00 a	37.50 a
Summer	MAT+REM	20.25 a	3.25 a	-	2.00 a	18.75 b	17.00 a	49.50 a
Summer	MAT	20.50 a	6.50 a	-	6.50 a	23.50 ab	23.25 a	40.25 a
Summer	REM+TOR	9.50 a	4.50 a	-	5.00 a	26.50 ab	23.75 a	52.50 a
Summer	CONT	15.75 a	5.00 a	-	1.00 a	43.00 ab	36.00 a	53.00 a
Fall	MAT+REM	15.25 a	-	1.75 a	3.00 a	26.00 ab	19.25 a	50.25 a
Fall	MAT	17.25 a	-	1.25 a	8.25 a	32.50 ab	20.50 a	38.25 a
Fall	REM+TOR	13.25 a	-	0.50 a	6.00 a	27.75 ab	20.00 a	53.25 a
Fall	CONT	19.75 a	-	0.25 a	6.00 a	45.00 ab	40.50 a	55.75 a

[1] Within a column, means followed by different letters are significantly different at $P<0.05$.

APPENDIX I

PRE AND POST-TREATMENT BARE GROUND

BUSH RANCH

Season of Application	Treatment	2010				2011		
		APR	JUL	OCT	NOV	MAY	JUL	OCT
		% cover						
Spring	MAT+REM	16.75 a[1]	-	-	1.50 a	0.75 a	2.50 a	1.00 a
Spring	MAT	6.25 a	-	-	8.00 a	4.50 a	4.50 a	1.75 a
Spring	REM+TOR	14.00 a	-	-	4.50 a	1.00 a	3.75 a	0.75 a
Spring	CONT	6.25 a	-	-	4.75 a	4.00 a	4.00 a	4.00 a
Summer	MAT+REM	17.25 a	22.50 a	-	8.00 a	6.75 a	9.00 a	4.00 a
Summer	MAT	7.50 a	21.75 a	-	10.00 a	7.50 a	8.00 a	5.00 a
Summer	REM+TOR	19.25 a	18.50 a	-	2.00 a	2.75 a	3.50 a	1.50 a
Summer	CONT	15.50 a	22.00 a	-	4.25 a	3.25 a	4.25 a	2.50 a
Fall	MAT+REM	11.75 a	-	6.50 a	2.00 a	2.50 a	2.25 a	1.50 a
Fall	MAT	8.50 a	-	12.75 a	1.50 a	3.50 a	3.50 a	1.50 a
Fall	REM+TOR	7.75 a	-	7.50 a	2.00 a	2.00 a	3.75 a	1.50 a
Fall	CONT	10.50 a	-	11.25 a	5.50 a	5.00 a	4.00 a	4.00 a

[1] Within a column, means followed by different letters are significantly different at $P<0.05$.

HITCHCOCK RANCH

Season of Application	Treatment	2010 APR	2010 JUL	2010 OCT	2010 NOV	2011 MAY	2011 JUL	2011 OCT
		% cover						
Spring	MAT+REM	5.00 a[1]	-	-	0.25 a	0.00 a	0.00 a	0.00 a
Spring	MAT	19.25 a	-	-	6.00 a	0.50 a	1.50 a	7.00 a
Spring	REM+TOR	7.25 a	-	-	0.00 a	0.00 a	0.00 a	0.50 a
Spring	CONT	16.50 a	-	-	11.75 a	20.50 a	21.75 a	45.00 a
Summer	MAT+REM	15.00 a	23.25 a	-	11.75 a	8.50 a	15.25 a	7.25 a
Summer	MAT	16.00 a	18.75 a	-	18.75 a	9.00 a	11.25 a	14.75 a
Summer	REM+TOR	23.50 a	23.50 a	-	14.25 a	8.50 a	5.25 a	10.00 a
Summer	CONT	26.25 a	29.25 a	-	15.75 a	21.00 a	24.75 a	27.50 a
Fall	MAT+REM	15.50 a	-	4.75 a	14.50 a	19.50 a	20.25 a	18.00 a
Fall	MAT	17.00 a	-	4.75 a	18.75 a	23.00 a	22.25 a	21.75 a
Fall	REM+TOR	16.00 a	-	6.00 a	5.00 a	15.00 a	12.25 a	21.50 a
Fall	CONT	10.50 a	-	2.25 a	4.75 a	5.25 a	9.00 a	19.75 a

[1] Within a column, means followed by different letters are significantly different at $P<0.05$.

APPENDIX J

PRE AND POST-TREATMENT HUISACHE LIVING CANOPY HEIGHT

BUSH RANCH

Season of Application	Treatment	2010 APR	2010 JUL	2010 OCT	2010 NOV	2011 MAY	2011 JUL	2011 OCT
		m						
Spring	MAT+REM	0.99 a[1]	-	-	0.00 a	0.80 abc	0.86 abc	0.97 abc
Spring	MAT	0.78 a	-	-	0.63 a	0.52 abc	0.81 abc	0.83 bc
Spring	REM+TOR	0.79 a	-	-	0.88 a	0.72 abc	0.76 abc	0.93 abc
Spring	CONT	0.98 a	-	-	1.39 a	1.35 a	1.32 a	1.43 a
Summer	MAT+REM	1.10 a	1.21 a	-	0.00 a	0.37 bc	0.62 bc	0.71 bc
Summer	MAT	1.10 a	1.17 a	-	0.00 a	0.57 abc	0.84 abc	0.85 bc
Summer	REM+TOR	1.05 a	1.16 a	-	0.00 a	0.65 abc	0.90 abc	1.00 abc
Summer	CONT	1.08 a	1.06 a	-	1.27 a	1.24 a	1.27 a	1.41 a
Fall	MAT+REM	1.10 a	-	1.41 a	0.00 a	0.70 abc	1.04 ab	1.10 abc
Fall	MAT	1.02 a	-	1.21 a	0.00 a	0.26 c	0.35 c	0.64 c
Fall	REM+TOR	1.05 a	-	1.50 a	0.00 a	1.00 abc	1.07 ab	1.18 ab
Fall	CONT	1.00 a	-	1.16 a	1.20 a	1.19 ab	1.15 a	1.22 ab

[1] Within a column, means followed by different letters are significantly different at $P<0.05$.

HITCHCOCK RANCH

Season of Application	Treatment	2010 APR	2010 JUL	2010 OCT	2010 NOV	2011 MAY	2011 JUL	2011 OCT
		m						
Spring	MAT+REM	1.00 abc[1]	-	-	0.00 a	0.42 ab	0.62 ab	0.10 f
Spring	MAT	0.90 c	-	-	0.00 a	0.50 ab	0.52 a	0.61 ef
Spring	REM+TOR	0.95 bc	-	-	0.00 a	0.44 ab	0.85 ab	0.98 cde
Spring	CONT	0.92 bc	-	-	1.54 c	1.60 c	1.69 c	1.69 ab
Summer	MAT+REM	1.24 a	1.45 a	-	0.00 a	0.51 ab	0.88 ab	1.17 bcd
Summer	MAT	1.18 ab	1.40 a	-	0.00 a	0.76 b	0.80 ab	0.89 cde
Summer	REM+TOR	1.09 ab	1.25 a	-	0.70 b	0.70 b	0.83 ab	0.85 cde
Summer	CONT	1.18 ab	1.40 a	-	1.60 c	1.71 c	1.80 c	1.85 a
Fall	MAT+REM	1.15 abc	-	1.37 a	0.00 a	0.00 a	0.50 a	0.62 def
Fall	MAT	1.25 a	-	1.56 a	0.00 a	0.00 a	0.57 ab	0.86 cde
Fall	REM+TOR	1.26 a	-	1.68 a	0.00 a	1.07 bc	1.26 bc	1.29 abc
Fall	CONT	1.14 abc	-	1.48 a	1.60 c	1.66 c	1.68 c	1.80 a

[1] Within a column, means followed by different letters are significantly different at $P<0.05$.

APPENDIX K

MEAN APPARENT MESQUITE MORTALITY VALUES COLLECTED FALL 2011 BASED ON ALL INDIVIDUALS LOCATED WITHIN EACH PLOT

Season of Application	Treatment	Site			
		Bush Ranch		Hitchcock Ranch	
		mean # mesquite	% mortality	mean # mesquite	% mortality
Spring	MAT+REM	4.25	95.83 a[1]	0.00	-
	MAT	2.50	54.17 ab	0.75	100.00 a
	REM+TOR	5.25	41.67 ab	0.75	100.00 a
	CONT	6.25	0.00 b	4.50	0.00 b
Summer	MAT+REM	3.75	45.00 ab	4.50	81.61 a
	MAT	6.50	42.71 ab	4.25	70.37 a
	REM+TOR	4.00	0.00 b	9.00	15.63 b
	CONT	7.00	0.00 b	4.50	0.00 b
Fall	MAT+REM	4.00	10.42 b	6.00	2.27 b
	MAT	7.00	13.54 b	4.50	10.00 b
	REM+TOR	5.25	3.57 b	4.75	0.00 b
	CONT	6.75	0.00 b	4.75	0.00 b

[1] Within a column, means followed by different letters are significantly different at $P<0.05$.

VITA

Name: Joshua Allan McGinty

Address: Department of Ecosystem Science and Management
2138 TAMU
College Station, TX, 77843

Email Address: jmcginty@tamu.edu

Education: B.S., Natural Resource Management, Angelo State University, 2009
M.S., Rangeland Ecology and Management, Texas A&M University, 2012